TR 65-129

TECHNICAL REPORT NO. 65-129

OPERATION OF TFSO

Quarterly Report No. 2, Project VT/5055

1 August through 31 October 1965

THE GEOTECHNICAL CORPORATION

3401 SHILOH ROAD GARLAND, TEXAS

TECHNICAL REPORT NO. 65-129

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1 August through 31 October 1965

Sponsored by

Advanced Research Projects Agency
Nuclear Test Detection Office
ARPA Order No. 624

TELEDYNE INDUSTRIES, INC.
GEOTECH DIVISION
3401 Shiloh Road
Garland, Texas

November 12, 1965

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IDENTIFICATION

AFTAC Project No:	VELA T/5055
Project Title:	Operation of TFSO
ARPA Order No:	624
Name of Contractor:	The Geotechnical Corporation, Garland, Texas
ARPA Program Code No:	5810
Contract Number:	AF 33(657)-14444
Effective Date of Contract:	12 April 1965
Amount of Contract:	$758,784.00
Contract Expiration Date:	31 October 1966
Program Manager:	B. B. Leichliter, BR 8-8102

ABSTRACT

Project VT/5055 includes the operation, evaluation, and improvement of the Tonto Forest Seismological Observatory located near Payson, Arizona. It also includes a discussion of special seismological investigations using data recorded by eight Long-Range Seismic Measurements Project seismological stations operating in an extended array configuration around the observatory. The work accomplished under Project VT/5055 from 1 August through 31 October 1965 is reviewed in detail.

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OPERATION OF TONTO FOREST SEISMOLOGICAL OBSERVATORY

1. INTRODUCTION

1.1 AUTHORITY

The research described in this report was supported by the Advanced Research Projects Agency, Nuclear Test Detection Office, and was monitored by the Air Force Technical Applications Center under Contract AF 33(657)-14444. The contract was dated 12 April 1965; the statement of work for Project VT/5055 is included as the appendix to this report.

1.2 HISTORY

The Tonto Forest Seismological Observatory (TFSO) was originally constructed by the United States Corps of Engineers in 1963. TFSO was designed to record seismic events and to be used as a laboratory for testing, comparing, and evaluating advanced seismograph equipment and seismic recording techniques. The instrumentation was assembled, installed, and operated until 30 April 1965 by the Earth Sciences Division of Teledyne Systems Company under Contract AF 33(657)-7747. In March 1964, the Long-Range Seismic Measurements (LRSM) Program provided eight mobile seismic recording vans to extend the existing instrument arrays at TFSO. On 1 May 1965, Geotech assumed the responsibility for operating TFSO.

The location of TFSO and the LRSM extended array sites are shown in figure 1. The TFSO buildings are shown in figure 2.

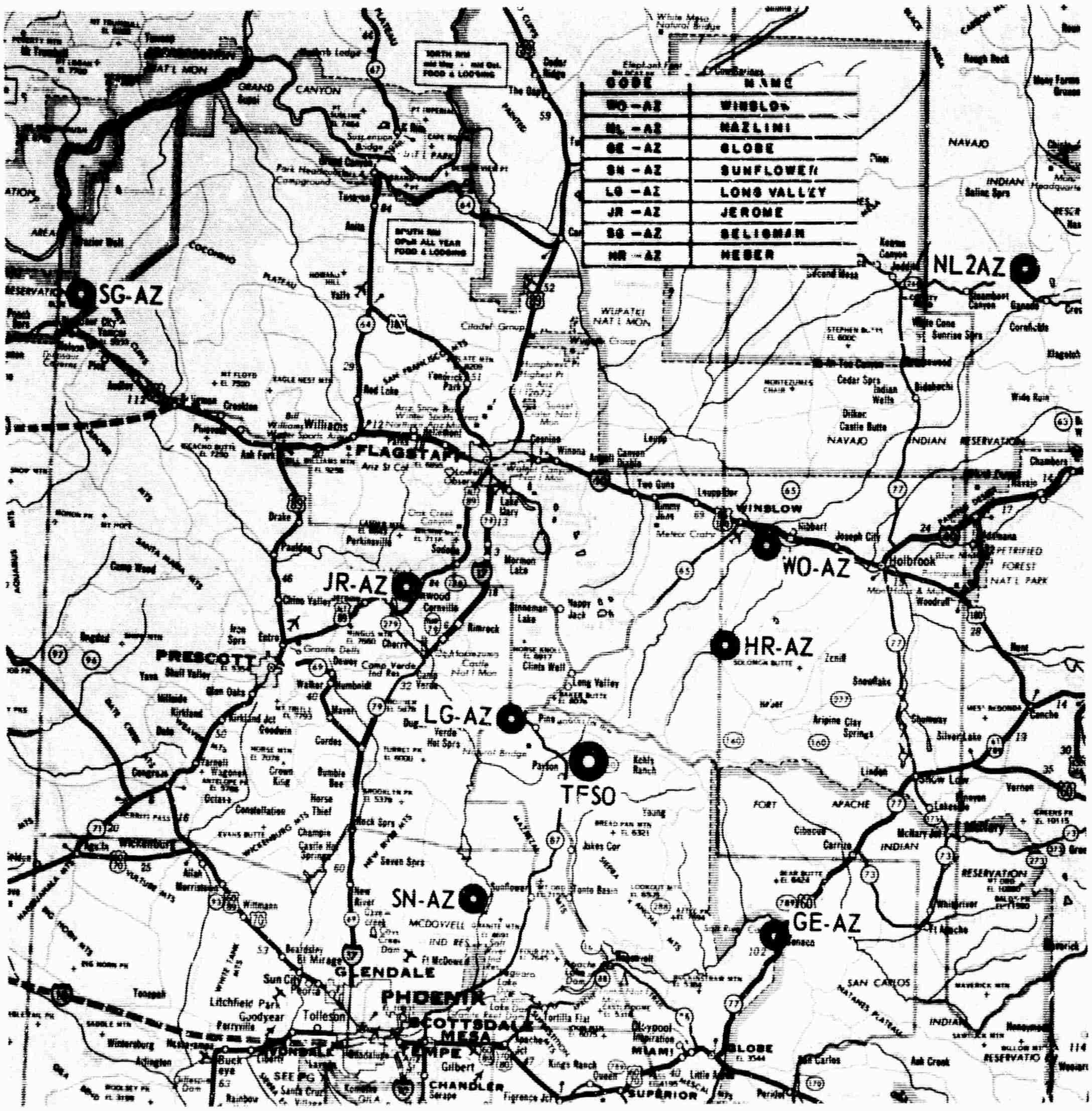


Figure 1. Locations of TFSO and extended array sites

Figure 2. TFSO, looking southwest

2. OPERATION OF TFSO

2.1 GENERAL OPERATIONS

2.1.1 Visit by Project Officer

Captain Munzlinger visited the Geotech offices in Garland, Texas during the period of 25 October through 27 October for the purpose of reviewing the status of Projects VT/5055, VT/5054, and VT/4054.

2.1.2 Detection of Project Long Shot

An underground nuclear explosion at Amchitka Island, Alaska, was detonated on 29 October 1965. The event was recorded at TFSO and the results were reported to AFTAC through the LRSM Program. The seismograms were forwarded to the Seismological Data Laboratory (SDL).

2.1.3 Visit by Phoenix Chamber of Commerce

On 17 September, 56 members of the Intercities Relations Committee of the Phoenix Chamber of Commerce toured the observatory. This committee had previously selected the observatory as the most interesting industry in the Payson area.

2.1.4 Calibration of Test Equipment

A procedure has been initiated in which test instruments are sent periodically to Metercraft Inc., Phoenix, Arizona, for calibration. Three tests instruments were sent to Phoenix for calibration on 6 October. An estimate of the cost and time required to calibrate the remaining station test equipment will be made, and a program will be planned for future equipment calibration.

2.1.5 Failure of Astrodata Digital Equipment

Data were lost from 1400Z on 11 September to 0000Z on 16 September due to a failure of the Astrodata Seismic Data Aquisition System. High voltage from the power supply caused numerous components to fail. A total of 42 transistors and 38 diodes, capacitors, and lamps were damaged. Later models of this power supply have been modified to prevent such an occurrence in the future. The power supply at TFSO has been modified. A detailed report of this failure was submitted to the Project Officer. After necessary repairs were made, equipment operation was resumed until 0000Z, 4 October 1965, at which time the LRSM vans were shut down.

2.1.6 Time Code Management Data Generator (TCMDG) Carrier Frequency Change

The carrier frequency for TCMDG on tape recorders number 2, 3, and 6 was changed from 60 cps to 10 cps on 19 October 1965.

2.1.7 Control of Data Channel Assignments

In compliance with AFTAC specifications, each data format recorded at each observatory is assigned a data group number. When a data format is changed, a new data group number is assigned to the format. Data format change notices reflecting the changes in channel assignments and data group numbers are routinely submitted to the Project Officer and to TFSO data users.

2.1.8 Completion and Shipment of Station Logs, Film, and Magnetic Tape

The magnetic-tape seismograms are shipped from TFSO each week. Three of the magnetic-tape units record data for AFTAC-SDL and three are for use by universities (presently the California Institute of Technology, Cal Tech). When data are not required by the university from all three magnetic-tape units, the observatory notifies AFTAC.

Film records from nine Develocorders are shipped routinely to data users. The film and magnetic-tape operations logs are made up in duplicate sets. Sets of selected Develocorder record prints are sent to Geotech regularly and to other data users on special request.

2.1.9 Safety at TFSO

TFSO has an adequate number of first aid and snake bite kits. Personnel have been briefed on the location and use of these kits. Personnel have also been briefed on the location and use of the 24 fire extinguishers at TFSO. In addition, there are two outside fire hoses and hydrants and a fire alarm system which has several detectors in the central recording building and one in the mechanical equipment building. All safety equipment is checked monthly.

2.2 EVALUATE SEISMIC DATA AND DETERMINE OPTIMUM OPERATIONAL CHARACTERISTICS

2.2.1 Vault Refit Project

A program to modify the short-period vaults was started in June. Figures 3 and 4 show a vault and vault cover after refit. The refit program for the tank vault housing the short-period horizontal seismometers was completed on 20 July. The refit program for the tank vaults housing the short-period vertical seismometers was completed on 20 September. Prior to the refit program, 25 percent of the vaults had between one-half and 19 inches of water in them. In all instances where water had been above the seismometer case seal, the seismometer was replaced. The seismometer originally installed in the vault was thoroughly cleaned and checked for proper operation before being reinstalled in another vault.

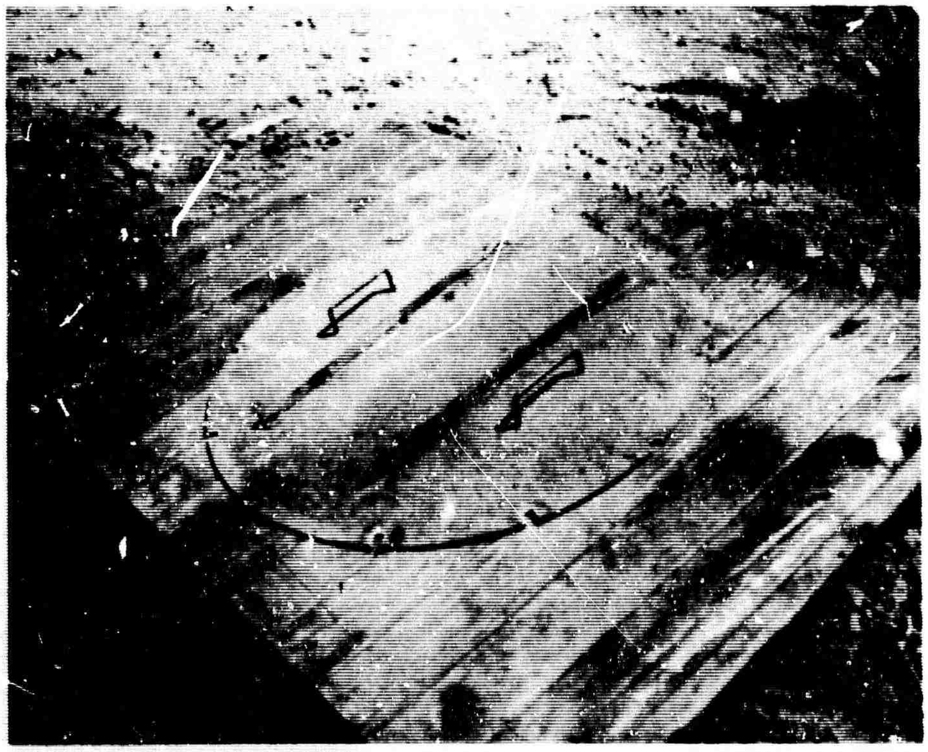


Figure 3. Modified vault cover

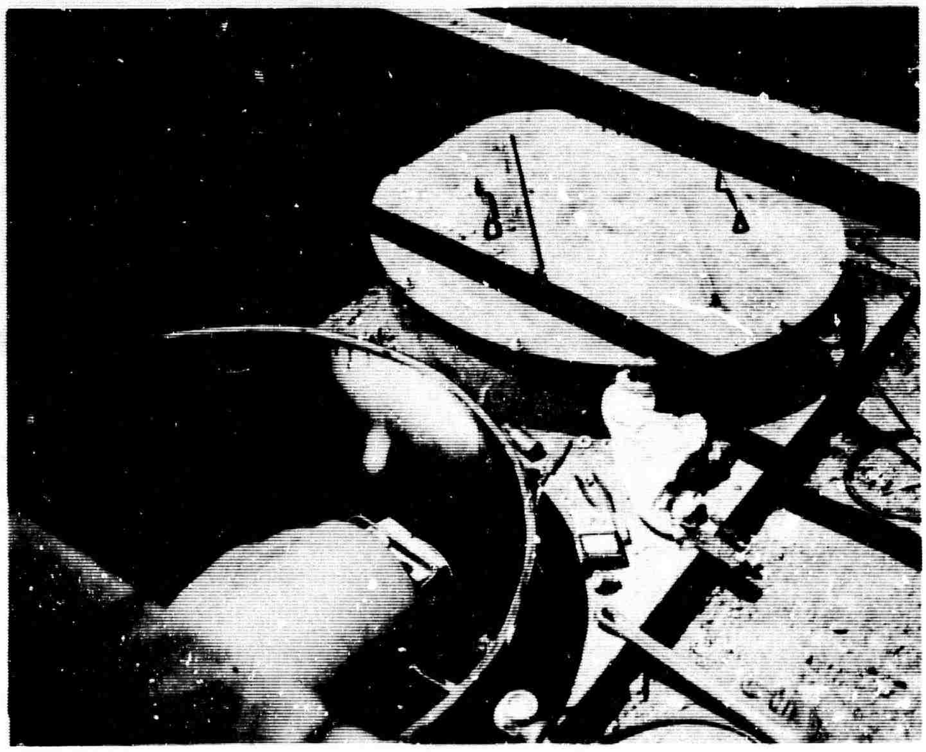


Figure 4. Vault after refit.

Two short-period horizontal vaults, (NE 92 and SE 91) were reopened approximately three weeks after refit had been completed. The "high-water" mark in the pits surrounding the vaults was above the vault lids. When the vault lids were removed, the inside of the vaults were found to be dry and in good condition.

The vaults housing the short-period horizontal instruments, previously refitted, were reopened so that final weight-lifts and G checks could be made on the seismometers. All calibrator motor constants were adjusted to within ±2% of 0.296 newton/ampere from the previous value of 0.387. This was done to permit calibration of all short-period seismometers using the same value of calibration current. While the vaults were open, the southeast horizontal seismometers were reoriented 180 degrees. This was done because the seismometers had been installed in an unconventional manner with the result that lifts and dc pulses produced outputs of opposite polarity. This made it difficult to interpret seismograph polarity when making weight lifts. All short-period horizontal seismometer bearings were checked and set to 127.5° (R) and 217.5° (T). Effective 1 October 1965, the designators for the horizontal seismographs of the TFSO linear array were changed from "SE" to "R" (radial) and from "NE" to "T" (transverse). All seismograph number designations remain unchanged.

The horizontal instrument field work was completed on 8 October. This completed all short-period instrument and vault work except that in the underground vaults.

?.2.2 Results of Calibration Motor Constant Checks

The calibrator motor constants (G) of all JM short-period seismometers (47 verticals and 26 horizontals) were checked by manual weight lifts during the reporting period. The observed value of "G" was in each case compared with the value determined during previous checks which, for most seismometers, occurred prior to 1 May 1965. Average changes of 1.7 percent and 5.5 percent were noted for the "G" of the vertical and horizontal instruments; respectively. A change greater than 5 percent was observed on 8 percent of t[illegible]rtical seismometers and 58 percent of the horizontal seismometers. The maximum deviations were 6.7 percent for the vertical seismometers and 13 percent for the horizontal seismometers. The larger percentage change in the horizontal seismometers is attributed primarily to the fact that an effective weight of 0.2 gram was used whereas the previous checks had been made with a 0.5 gram effective weight. As discussed in TR 65-58, an effective weight greater than 0.2 gram sh uld not be used to check "G". If larger effective weights are used a slightly erroneous [illegible]alue of "G" will result.

2.2.3 Installation of the AEI Lightning Protection System and Reported Storms and Storm Damage

By the end of September all circuits at TFSO were protected by the AEI type protectors except those data and calibration circuits between the Central Recording Building (CRB) and the west underground vault. Presently, the only data circuits from this vault are two J-M high-frequency systems and a three-component set of Benioff seismometers. A photograph of the AEI protectors is shown in figure 5.

There were a number of electrical storms at TFSO during this reporting period. Damage was confined mainly to fuses and carbon blocks in exterior circuits that were not yet converted to the AEI protectors. Some data were lost due to damaged or "flipped" galvanometers and a damaged PTA power supply.

2.2.4 Peristaltic Pumps for Develocorders

Nine new peristaltic pumps for the Develocorders were received on 24 June 1965, and installation was begun on 1 July 1965. By the end of July, four of the new pumps had been installed. Five more pumps were installed during August to complete the modification of all nine "on line" Develocorders.

During September two of the peristaltic pumps failed. The trouble, in each case, was found to be a malfunctioning gear train. These assemblies have been replaced and no further trouble has been experienced. The new peristaltic pumps have improved the quality of the film seismogram, because they are more reliable than the original pumps.

2.2.5 Long-Period System Change

Six 30-second Lehner-Griffith galvanometers (on loan from LRSM) were received during August. These galvanometers were installed in a three-component Sprengnether seismograph system and in the horizontal components of the standard TFSO long-period system, pending acquisition of 100-second Harris galvanometers.

The Sprengnether long-period three-component system was put into operation on 30 August to provide long-period data with a frequency response similar to that data being transmitted to TFSO from the LRSM vans. The data from

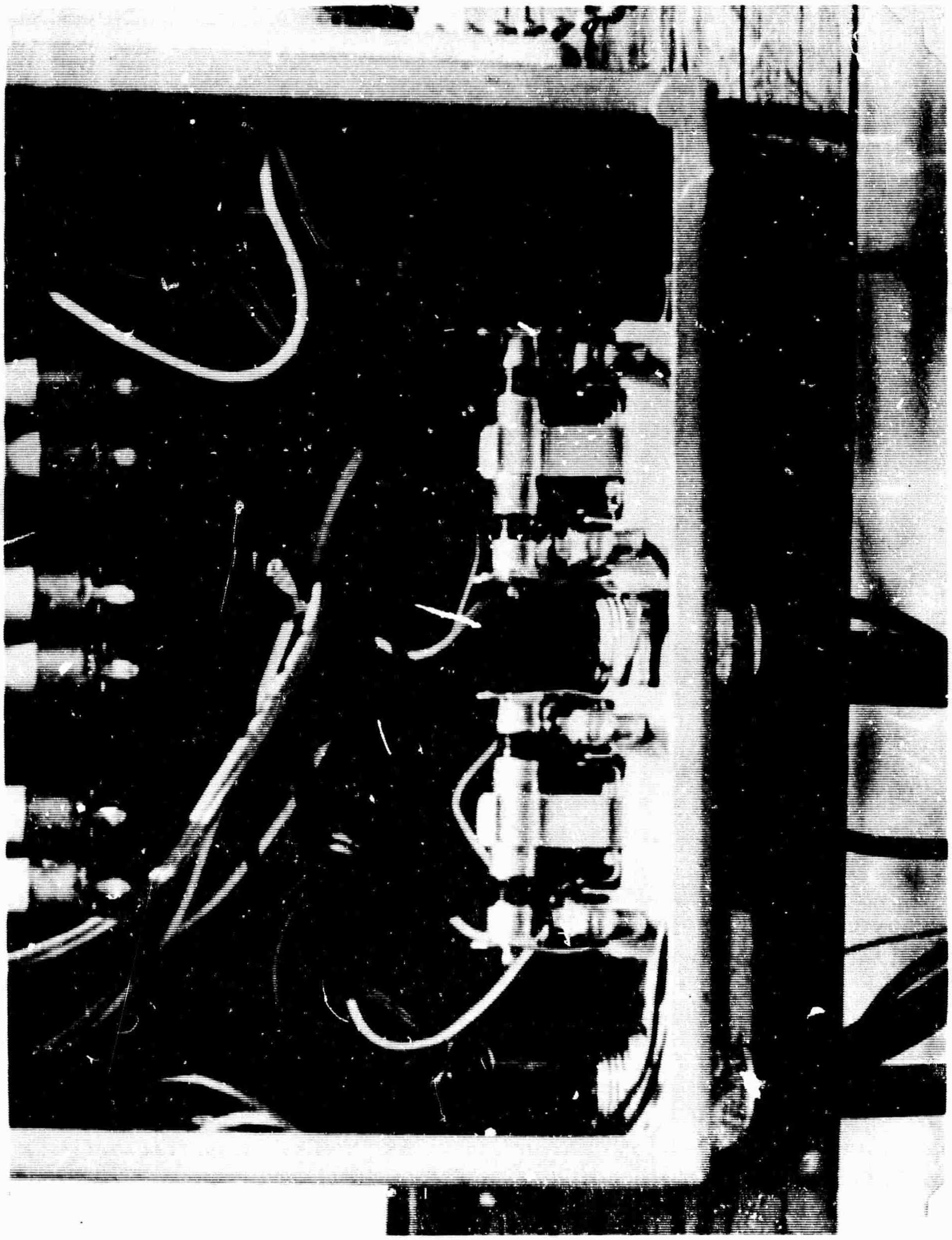


Figure 5. AEI protectors installed at TFSO.

these seismometers were recorded on digital-magnetic tape and on a Develocorder to meet the data-recording requirements for Texas Instruments Incorporated as discussed in section 2. 6. 1.

2. 2. 6 Marine Door for Long-Period Vault

The installation of a pressure-tight marine door for one of the pier rooms in the long-period vault was completed on 15 October 1965 (see figures 6 through 9). Long-period tests to evaluate benefits of the door are scheduled for November 1965.

2. 2. 7 Modification of Date Timer, Model 4800A

The Date Timer, Model 4800, for the Develocorder are being sent to Garland on a rotational basis for modification to the Model 4800A configuration. At the end of this reporting period, 50 percent of the date timers have been modified and reinstalled. Minor operational difficulties have been encountered with two of the modified units, however; these have been corrected.

2. 2. 8 Isolation Amplifier Instability

Operational amplifiers are used in the seismographs at TFSO to provide electrical isolation between various instruments in the system. Experience with these amplifiers has shown that their gain changes with time. Observatory personnel have indicated that the problem seems to be associated with the feedback potentiometers in the amplifiers. Plans are under way to modify ten of these amplifiers by replacing the present feedback potentiometer with a dust-sealed device which has better mechanical construction. Continued operation of the modified amplifiers should indicate whether an improvement in gain stability has been realized. If sufficient improvement is obtained by this modification, we will install dust-sealed potentiometers in the remaining isolation amplifiers at TFSO.

2. 2. 9 Standard Seismograph Operating Parameters

The operating parameters, and their tolerances are shown in table 1. These parameters are checked and reset, as necessary, when the frequency response of a seismograph is found out of tolerance. The response characteristics of the TFSO seismographs are shown in figure 10.

Figure 6. Marine door installation-LP vault.

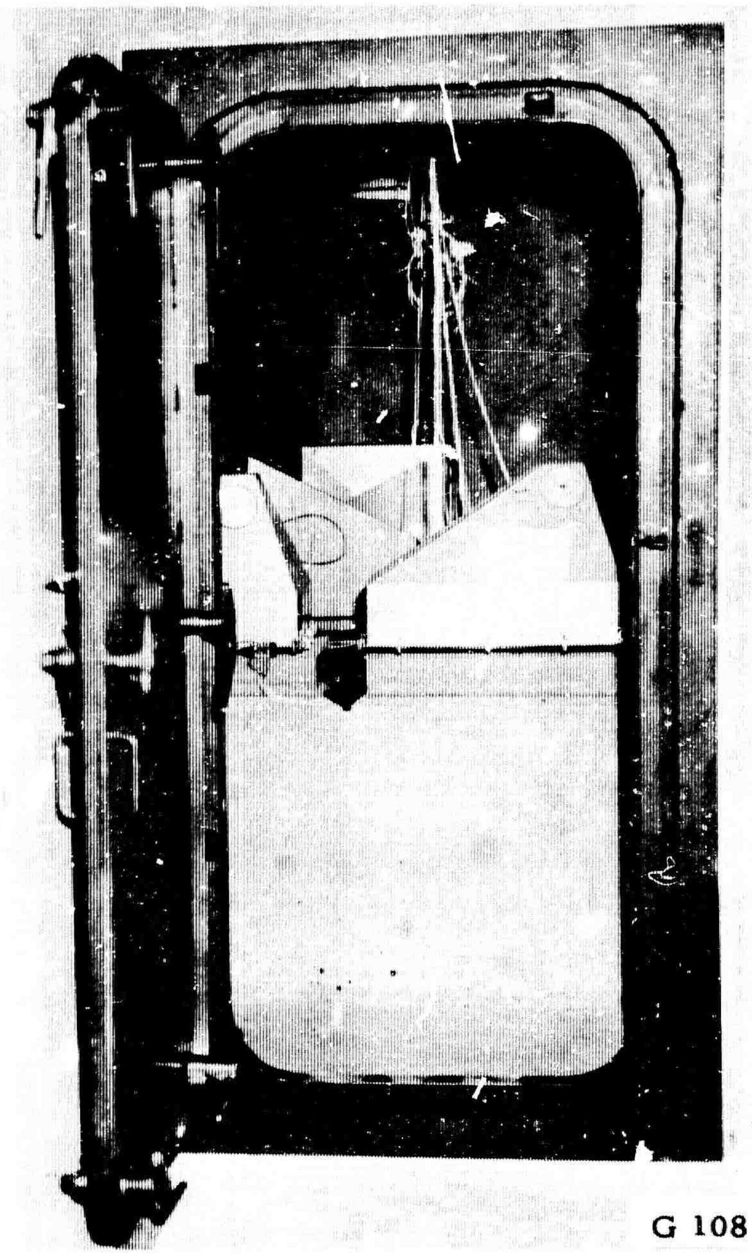


Figure 7. Marine door installation-LP vault.

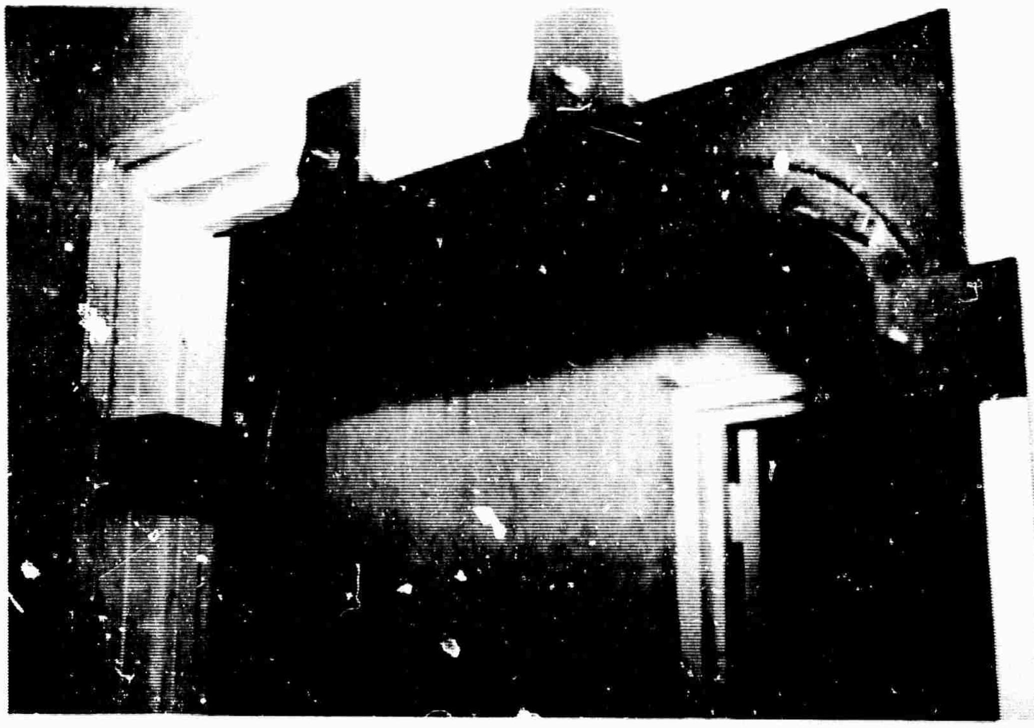


Figure 8. Inside top installation of marine door.

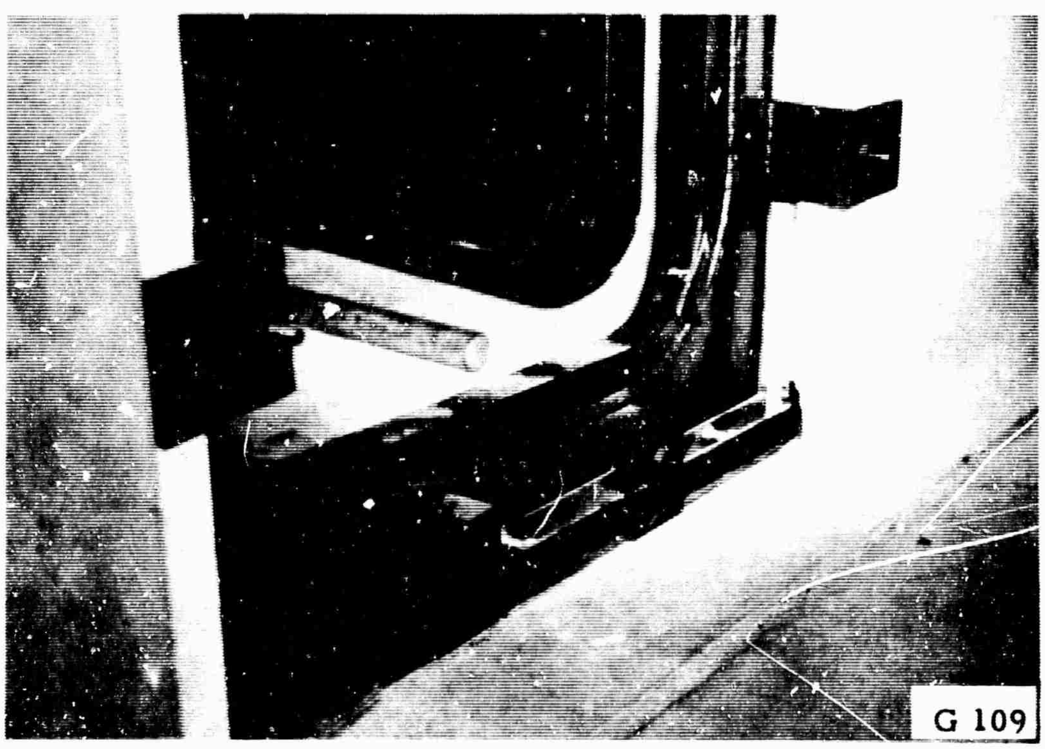


Figure 9. Inside bottom installation of marine door.

Seismograph				Operating parameters and tolerances				Filter settings	
System	Comp.	Type	Model	Ts	λs	Tg	λg	Bandpass at 3dB cutoff (sec)	Cutoff rate at SP side (dB/Oct)
SP	Z	Johnson-Matheson	6480	1.25 ±2%	0.54 ±5%	0.33 ±5%	0.65 ±5%	0.1 - 100	12
SP	H	Johnson-Matheson	7515	1.25 ±2%	0.54 ±5%	0.33 ±5%	0.65 ±5%	0.1 - 100	12
SP	Z	Benioff	1051	1.0 ±2%	1.0 ±5%	0.2 ±5%	1.0 ±5%	0.1 - 100	12
SP	H	Benioff	1101	1.0 ±2%	1.0 ±5%	0.2 ±5%	1.0 ±5%	0.1 - 100	12
SP	Z	UA Benioff	1051	1.0 ±2%	1.0 ±5%	0.75	1.0 ±5%		
SP	H	UA Benioff	1101	1.0 ±2%	1.0 ±5%	0.75	1.0 ±5%		
SP	H	Wood-Anderson	TS-220	0.8	0.78				
IB	Z	Melton	10012	2.5 ±5%	0.65 ±5%	0.64 ±5%	1.2 ±5%	0.05 - 100	18
IB	H	Lehner-Griffin	660	2.5 ±5%	0.65 ±5%	0.64 ±5%	1.2 ±5%	0.05 - 100	18
BB	Z	Press-Ewing	1260	12.5 ±5%	0.425 ±10%	0.64 ±5%	9.0 ±10%	0.05 - 100	18
BB	H	Press-Ewing	660	12.5 ±5%	0.425 ±10%	0.64 ±5%	9.0 ±10%	0.05 - 100	18
LP	Z	Geotech	7505A	20.0 ±5%	0.74 ±10%	110.0 ±10%	1.0 ±10%	25 - 1000	12
LP	H	Geotech	8700C	20.0 ±5%	0.620 ±10%	30.0* ±10%	0.591 ±10%	25 - 1000	12
								20 - 1000**	12

KEY

SP	Short period	T_s	Seismometer free period (sec)
IB	Intermediate band	T_g	Galvanometer free period (sec)
BB	Broad band	λ_s	Seismometer damping constant
LP	Long period	λ_g	Galvanometer damping constant
UA	Unamplified (i.e., earth powered)	*	See section 2.2.5

** With a 6-second notch filter

Table 1. Operating parameters and tolerances of seismographs at TFSO.

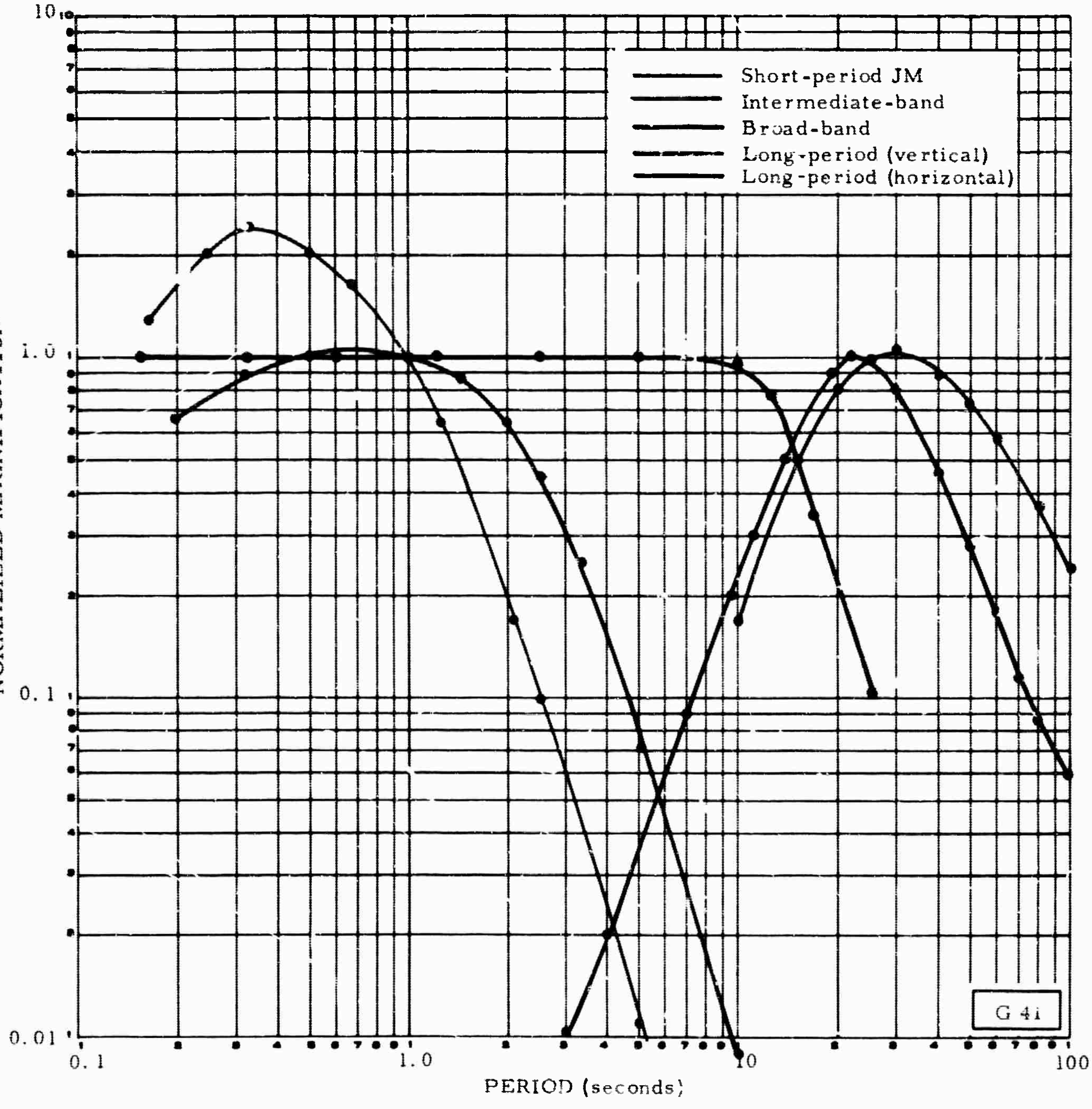


Figure 10. Normalized response characteristics of seismographs at TFSO

2.3 ANALYZE DATA AND REPORT RESULTS TO USC&GS AND SEISMIC DATA LABORATORY

2.3.1 Report Events to U. S. Coast and Geodetic Survey

During this reporting period, arrival time, period, and amplitude measurements of events recorded at TFSO were reported daily to the Director of the USC&GS in Washington, D. C. The number of events recorded, by type, are listed in table 2.

Table 2. Earthquake data reported to the USC&GS by TFSO from 1 May through 31 October 1965

May 1965					June 1965					July 1965				
L	N	R	T	PER[a]	L	N	R	T	PER[a]	L	N	R	T	PER[a]
2	71	18	933	71.8	3	128	21	991	76.1	0	185	19	953	79.3

August 1965					September 1965					October 1965				
L	N	R	T	PER[a]	L	N	R	T	PER[a]	L	N	R	T	PER[a]
9	102	20	1050	b	19	156	41	977	b	25	132	14	1048	b

KEY

- L Local
- N Near regional
- R Regional
- T Teleseism
- a Percentage of those events located by the USC&GS that were reported by the observatory - based on USC&GS "Earthquake Data Report"
- b Not available

2.3.2 Daily Analysis for Automated Bulletin Process

Data from TFSO are combined with the data from CPSO, BMSO, UBSO, and WMSO and published in a multistation earthquake bulletin. The June Automated Bulletin Process (ABP) is ≅ 85 percent complete. The bulletins for February, March, April, and May 1965, were published during this reporting period. Raw data for June, July, and August 1965, have been

keypunched, transcribed onto magnetic tape, and sent to SDL for processing. Keypunching of September raw data is about 50 percent complete.

2.4 QUALITY CONTROL

2.4.1 Routine Analysis Evaluation - Quality Control

Short-period and long-period 16-millimeter film seismograms and magnetic-tape records were routinely checked in Garland. It was found that these quality control checks were valuable to both observatory personnel and the Garland support personnel by helping to detect equipment malfunctions and areas of misunderstanding that might otherwise have gone undetected.

2.4.2 Quality Control of 16-Millimeter Film Seismograms

Short-period and long-period 16-millimeter film seismograms and routine analysis of these seismograms performed at TFSO were routinely checked and evaluated in Garland on a random basis. Following is a tabulation of the major items that were checked by the quality control analysts.

a. Film boxes - neatness and completeness of box markings;

b. Develocorder logs - completeness, accuracy, and legibility of logs;

c. Sixteen-millimeter film seismograms;

(1) Quality of the overall appearance of the record (e.g., trace spacing and trace intensity);

(2) Quality of film processing;

d. Analysis;

(1) Completeness and accuracy of the analysis;

For reporting to the USC&GS
For preparation of data for the earthquake bulletin

(2) Accuracy of all measurements;

(3) Completeness of analysis sheets:

Completeness of entries
Legibility of entries
Neatness of analysis sheets.

When the quality control check had been completed, a critique, the seismograms, the logs, and the analysis sheets were returned to the observatory for review and comment by the observatory personnel.

2.4.3 Quality Control of Magnetic-Tape Seismograms

Routine quality control checks of randomly selected magnetic-tape seismograms were made in Garland to assure that recordings met specified standards. The following are among the items that were checked by the quality control group.

a. Tape and box labeling;

b. Accuracy, completeness, and neatness of logs;

c. Adequate documentation of logs by voice comments on tape;

d. Seismograph polarity;

e. Level of calibration signals;

f. Relative phase shift between array seismographs;

g. Level of the microseismic background noise;

h. Level of the system noise;

i. PTA dc balance;

j. Oscillator alignment;

k. Quality of the recorded WWV signal;

l. Time pulse carrier;

m. Digital time marks.

2.5 TELEPHONE AND VHF TELEMETRY BETWEEN TFSO AND LRSM VANS

2.5.1 Termination of Telemetry and Generator Systems

The telephone and VHF telemetry system which transmitted data from the eight LRSM vans in the Extended Array to TFSO were operated until the vans were shut down on 4 October. The generators at Globe and Heber, Arizona and at Myrtle Point, which supplied power for the two VHF links, were also shut down on 4 October. These generators can be made operational within 24 hours after notice. The cutoff problem which had been experienced with the 1.5 KW generators at Globe and Heber was remedied by providing better ventilation in the generator building.

2.5.2 Modification of the Data Acquisition System

Modification of the Astrodata system was accomplished at TFSO on 11 August 1965. By an increase in tape speed, the tape density write pattern was changed from 800 bpi to 556 bpi. This changed the recording time from approximately 96 minutes per reel to approximately 67 minutes per reel.

2.6 PROVIDE FACILITIES AND ASSISTANCE TO OTHER GROUPS

2.6.1 Digital Recording for Texas Instruments

Texas Instruments had conducted a study for which they required special digital data to be recorded at TFSO. Figure 11 shows the digital recording equipment. The data were recorded over a two-month period using the observatory instrumentation and data from the eight LRSM extended array sites. Data from seismic events as well as seismic background noise at high and low magnifications were recorded. This program was scheduled to begin on 1 July but several problems developed that delayed the recording of data. Texas Instruments required recordings of both low and high magnification data. The low-magnification data could be recorded using normal TFSO magnification settings. The high-magnification recording was specified to drive the Astrodata equipment within 6 to 10 dB of clipping when recording the normal background noise. In order to record the data at this high magnification, it was necessary to increase the signal level output of the LRSM equipment. The increased signal level was accomplished at the LRSM recording vans and at TFSO just ahead of the digital data acquisition system.

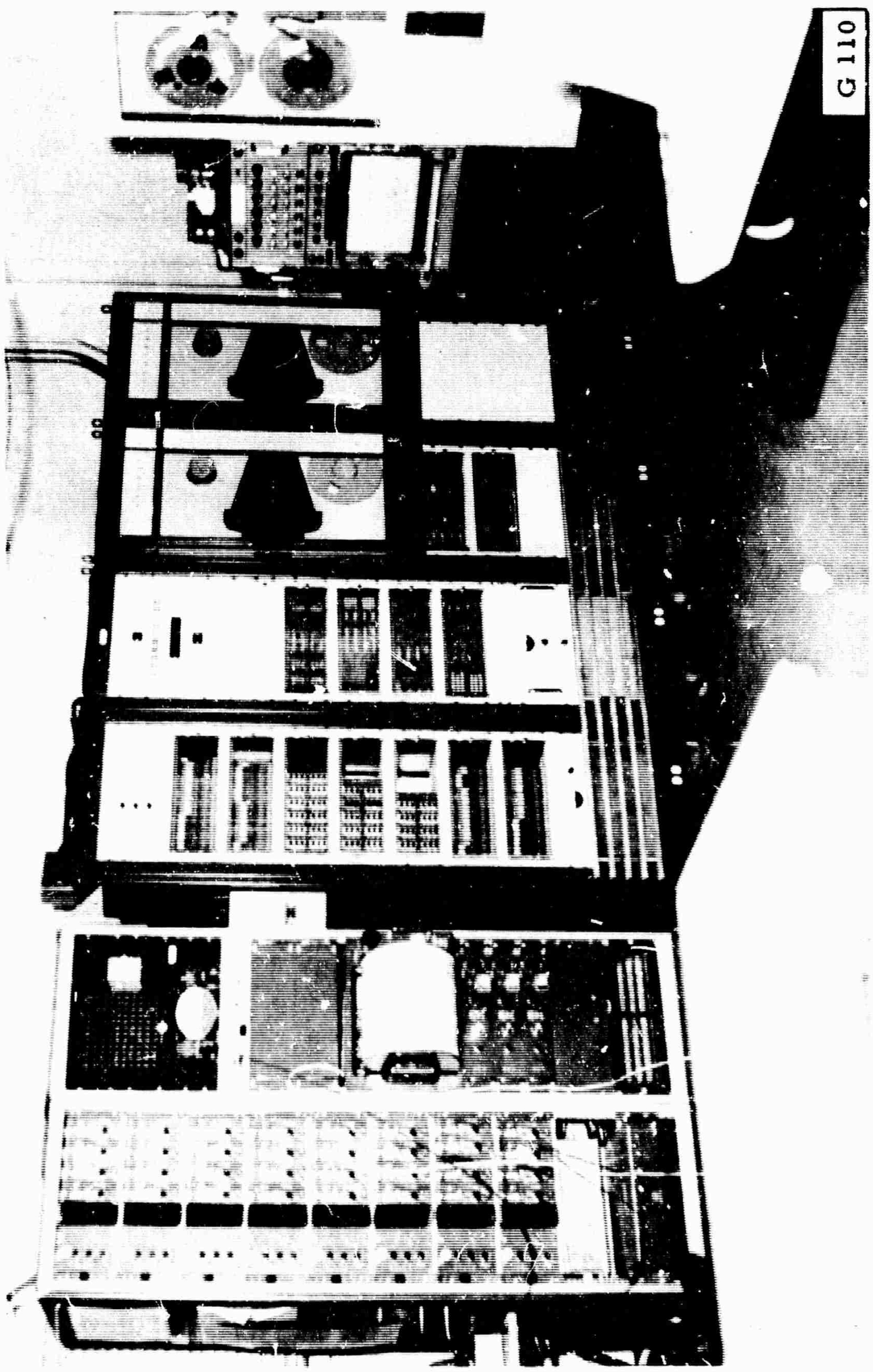


Figure 11. Astrodata digital recording equipment.

Short-period data from the three-component Benioff seismograph was used instead of data from the three-component JM seismograph. In addition, it was required that the TFSO long-period response be comparable to the LRSM long-period response.

Because of the required modifications of the telemetry system and instrumentation parameters, full-scale recording for Texas Instruments was postponed until the middle of August.

Operational amplifiers were installed and rewired as necessary and recording with the Astrodata digital equipment was started on 16 August 1965. All recordings were made with the low-magnification (normal) short-period recording format until 26 August when a 24-hour high-magnification short-period recording was started. Two temporary employees were hired to assist in the operation of the equipment on a 24-hour basis.

Recording with the Astrodata digital equipment continued until 0000Z, 4 October 1965. The LRSM vans in Arizona were shut down at this time. A new recording format for the digital equipment was sent to the Project Officer and approved.

2.6.2 Recording for California Institute of Technology

Dr. Stewart Smith of Cal Tech was notified of the LRSM van move on 29 September. He requested new data groups for the three magnetic-tape recorders and one Develocorder which are assigned for his use. The new formats were put in operation on 5 October 1965.

At the request of Dr. Smith, an experimental recording of a summation of two radial seismometers with the same magnification, but with opposite polarities was made in an effort to evaluate the cancellation of seismic signals. The same type of recording was made with two transverse seismometers. The data were given to Dr. Smith for evaluation.

2.6.3 Recording for University of California

Dr. R. A. Haubrich, Mr. Don Miller, and Mrs. Donita Swenson from the University of California, who had been operating the Ambilog 200 system since July (figure 12) for the purpose of studying "on-line" processing and extended array data, completed their work. This group departed with their equipment on 17 September 1965.

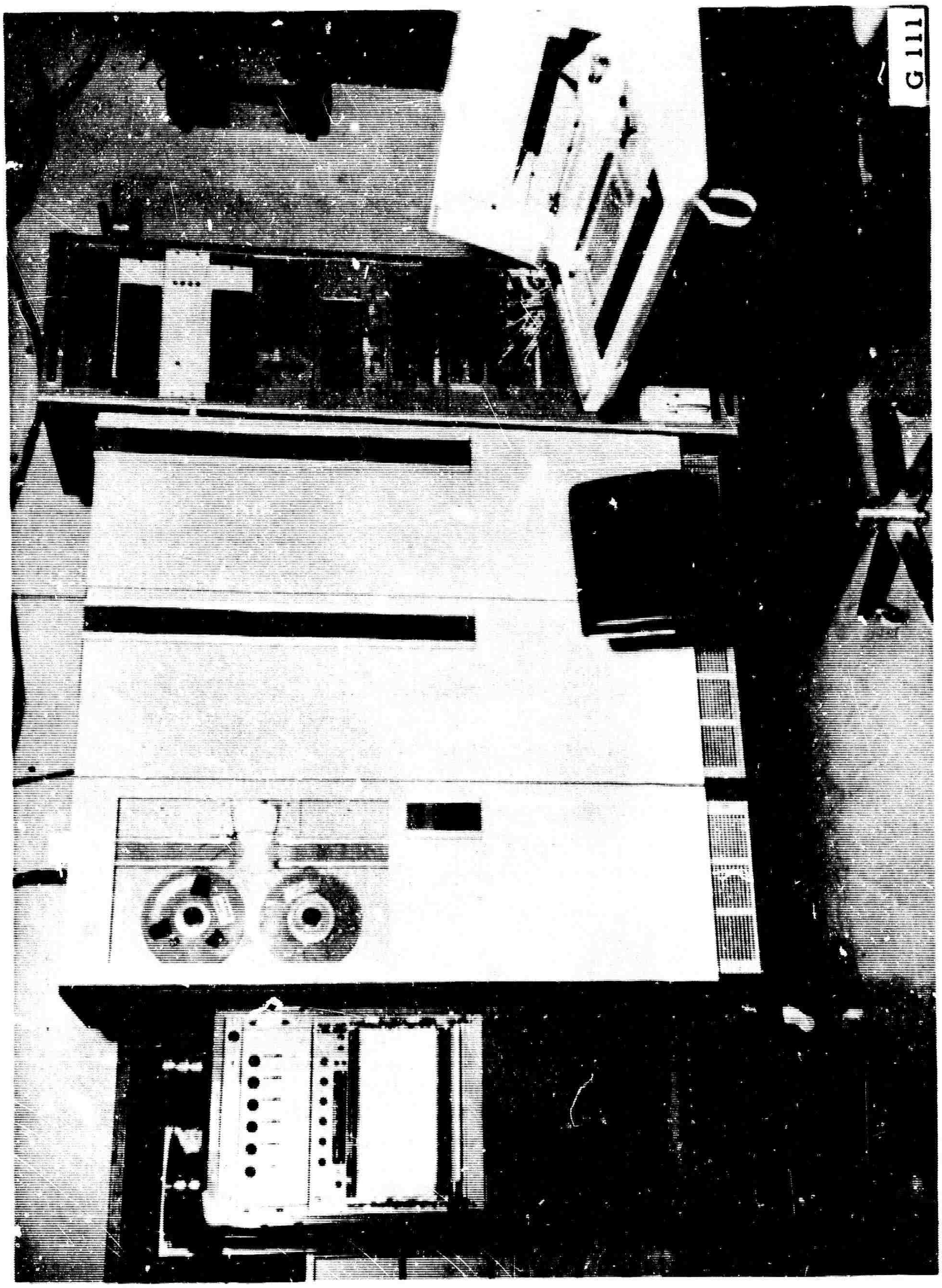


Figure 12. University of California ambilog 200 system.

2.6.4 Recording for Massachusetts Institute of Technology (MIT)

Mr. Larry Sargent and Mr. Robert Sheppard of MIT, visited TFSO on 15, 20, and 21 October 1965. The purposes of the visits were 1) to remove the 11-channel telemetering system and 2) to replace the 11-channel system with an 8-channel Geotech telemetry system. The 8-channel system is presently transmitting the data from the three-component SP Benioff seismographs, the three-component LP seismographs, Z1 and a summation of Z10, Z11, Z15, Z17, Z21, and Z22. The 11-channel telemetry system was subsequently installed in the LASA Data Center in Billings, Montana.

2.7 MAINTAIN TFSO FACILITIES

2.7.1 Furnace

Mr. Grimpe, from ASD visited TFSO on 27 April 1965 to inspect the station's heating system. He reported that the boiler was overheating and recommended its repair or replacement. On 21 October, Mr. C. W. Toberts, American Standard Plumbing and Heating Division, visited TFSO to inspect the furnace and to suggest methods of repair.

The unit at TFSO is an A-5 diesel oil-fired boiler and does not have a completely enclosed heating chamber inside the outer cover. Fire and smoke escape around the inspection plate, especially during initial combustion.

The following remedial action was taken:

a. The inspection plate was clamped in place and putty was forced into the gaps.

b. New insulation was packed into the side of the unit.

c. The jacket was cleaned and painted.

d. The draft controls were carefully adjusted so that most of the draft comes up through the bottom of the unit and the top draft was decreased so that the flame is primarily contained in the bottom of the unit.

A careful inspection of the furnace for the next few months will be necessary to assure that the desired corrections were made. If further recommendations are necessary, they will be made after the present modifications have been fully evaluated.

2.7.2 Condensation Under Roof of CRB

According to Mr. Grimpe, a moisture problem existed, especially during the winter, in the attic of the CRB where condensation accumulated on the inside of the insulated metal roof. The condensation occurred because the vapor barrier on the warm side of the insulation is inadequate. Mr. Grimpe recommended that attic ventilation be installed as a solution to the moisture problem.

During May, the attic was ventilated and, on the advice of Mr. G. Blau, Vice-President of Stiles and Allen, Mesa, Arizona, the ceiling in the CRB was insulated. Because the warmer air is now contained below the attic and the ventilation in the attic is increased, the temperature should remain below the condensation point.

It is recommended that no further work be done on the installation of a vapor barrier until the effects of the coming winter are observed. A procedure for checking the condensation will be established.

2.7.3 Air Chiller Problem and Solution

An excessive quantity of minerals in the local water supply have caused a considerable scale buildup in the chiller units of the air-conditioning system. A heavy acid treatment was applied to remove this scale, but continued use of acid treatment would damage the chillers, heat exchangers, etc. A chemical treatment of the water, to reduce the mineral content, was initiated during the previous quarter and the scale buildup during this reporting period has been considerably retarded.

3. DEVELOPMENTAL FUNCTION

A study of the feasibility of automatic calibration has been continued during this reporting period.

4. RESEARCH PROGRAMS

4.1 CONTINUE NOISE SURVEYS

Monthly noise surveys are being conducted at TFSO as part of the standard observatory analysis assignment.

4.2 WIND NOISE STUDY

Work is underway to determine the effects of wind-generated noise on the short-period seismographs of the TFSO array.

Preliminary results indicate that, in general, wind speeds up to 15 mph do not have a degrading effect on the TFSO short-period data. On few occasions winds in excess of 15 mph are observed. An evaluation of the effect of winds ranging from 10 mph to 25 mph was made from data recorded on 17 September 1965 when ideal winds for such a study were present. For this study 19 of the 31 elements of the short-period array were considered. Table 3 lists the wind-noise amplitudes in millimeters for the 19 elements.

Measurements were taken at X10 view and normalized to a magnification of 900 K. It is planned to operate a summation trace of 6 to 8 of the most quite short-period vertical seismographs. Then on windy days we will compare the operation and evaluate the various summations.

4.3 MAGNITUDE CORRECTION FACTORS

On 22 July, we submitted recommendations for a program designed to refine the estimates of the station magnitude correction factors developed under Project VT/036 and reported in TR 64-123, and to refine the distance-depth magnitude correction factors developed by Gutenberg and Richter. On 31 August, we received a letter from the Project Officer with approval of the proposed study. We plan to conduct this study jointly under Projects VT/5054 and VT/5055 using teleseismic P-phase data recorded at the five VELA-Uniform Seismological Observatories

4.4 EVALUATE COMBINATIONS OF EXISTING VERTICAL AND HORIZONTAL ARRAYS

During the last reporting period attempts were made to record the summation of Z1 - Z31 trace filtered with a Krohn Hite Filter, and the same summation with the standard operational filter. In the short-recording period, no conclusions could be made, but the results indicated that further evaluation is necessary. Now that the station Krohn Hite Filter is again available, it is planned to continue the evaluation of various filtered summations in an effort to find the optimum band-pass settings.

Table 3. Response of 19 short-period seismographs of the 31-element array to wind noise

(Averaged amplitude of trace deflection in millimeters, X10 view, peak-to-peak, normalized to 900K, at given wind velocities.)

Seismograph	25 mph	20 mph	15 mph	10 mph
Z1	8.2	10.9	4.7	3.5
Z2	9.1	11.8	5.2	3.0
Z3	8.6	11.7	4.9	2.5
Z8	6.0	4.1	8.3	4.7
Z11	17.2	22.5	8.0	4.3
Z12	2.9	5.1	4.0	4.0
Z13	29.6	11.5	8.8	3.0
Z14	21.0	13.0	13.0	7.6
Z16	26.2	19.8	10.2	11.3
Z19	11.0	6.0	6.5	5.0
Z21	26.0	15.0	5.1	5.0
Z22	11.8	9.8	4.3	4.0
Z23	4.1	3.4	3.8	2.1
Z24	4.1	4.6	4.0	4.1
Z26	4.1	9.0	4.5	2.7
Z28	6.7	12.0	5.3	2.6
Z29	5.1	13.8	8.0	4.8
Z30	21.3	15.1	11.5	6.1
Z31	16.0	5.3	3.0	2.8

4.5 STUDIES TO DETERMINE P-PHASE TRAVEL TIME CORRECTIONS FOR BMSO, CPSO, TFSO, UBSO, AND WMSO

Preliminary P-arrival time-residual data for BMSO, CPSO, TFSO, UBSO, and WMSO were gathered under Project VT/1124 and were used to determine the P-phase association time-window widths for the ABP. The travel-time residuals, grouped by observatory, were further classified by epicentral distance (10-degree increments), USC&GS reported magnitude, and station-to-epicenter azimuth.

Utilizing the data already processed, we are determining "unbiased" travel-time corrections for each of the five observatories. In addition, the variation of station-travel-time corrections as a function of station-to-epicenter azimuth is being studied.

The effectiveness of each of the correction factors developed will be determined using the data recorded at each observatory recorded since August 1964. We anticipate that this study, including a report of the results, will require approximately 12 months.

A tentative statistical model for treating the data has been formulated. This model should give the travel-time correction for each station and the contribution to the variance of the observed residuals due to magnitude, distance, and azimuth.

4.6 INSTALLATION AND OPERATION OF HIGH-FREQUENCY SEISMOGRAPH SYSTEMS

On 8 September, TFSO was requested to install and operate five special high-frequency seismograph systems. Four of these systems, ZHF1, ZHF2, ZHF3, and ZHF4, were essentially identical to the systems being operated at that time at WMSO. The frequency responses and block diagrams of these systems are shown in figures 13 and 14. The fifth high-frequency system, ΣGF, is the summation of the outputs of 24 Century Model 12FL, 12 cps Geophones in an 880-foot array. The estimated frequency response of ΣGF is shown in figure 15.

Figure 16 shows the signal from CHASE No. IV, partially masked by the signal from a local blast, and figure 17 shows typical microseismic background noise recorded by the high-frequency systems. These systems were activated between 13 and 16 September; a copy of a TFSO memorandum report on these systems dated 20 September, was forwarded to the Project Officer. The data from these systems were recorded on both magnetic tape and 16 mm film. Periodic recording on 16 mm film at a rate twice as fast as the normal short-period recording speed was accomplished in an effort to better resolve some of the higher-frequency signals recorded.

On 1 October the Project Officer requested that all high-frequency channels be recorded at three levels on both FM and digital tape. The three levels to be 10, 30, and 50-60 dB below clipping. This was accomplished beginning 13 October. On 20 October, at the request of the Project Officer, the ZHF1, 2, and 4 channels were deleted and channels ZH5 and ZH6 were added (figure 18). The high-frequency systems were recorded at the intervals listed in table 4.

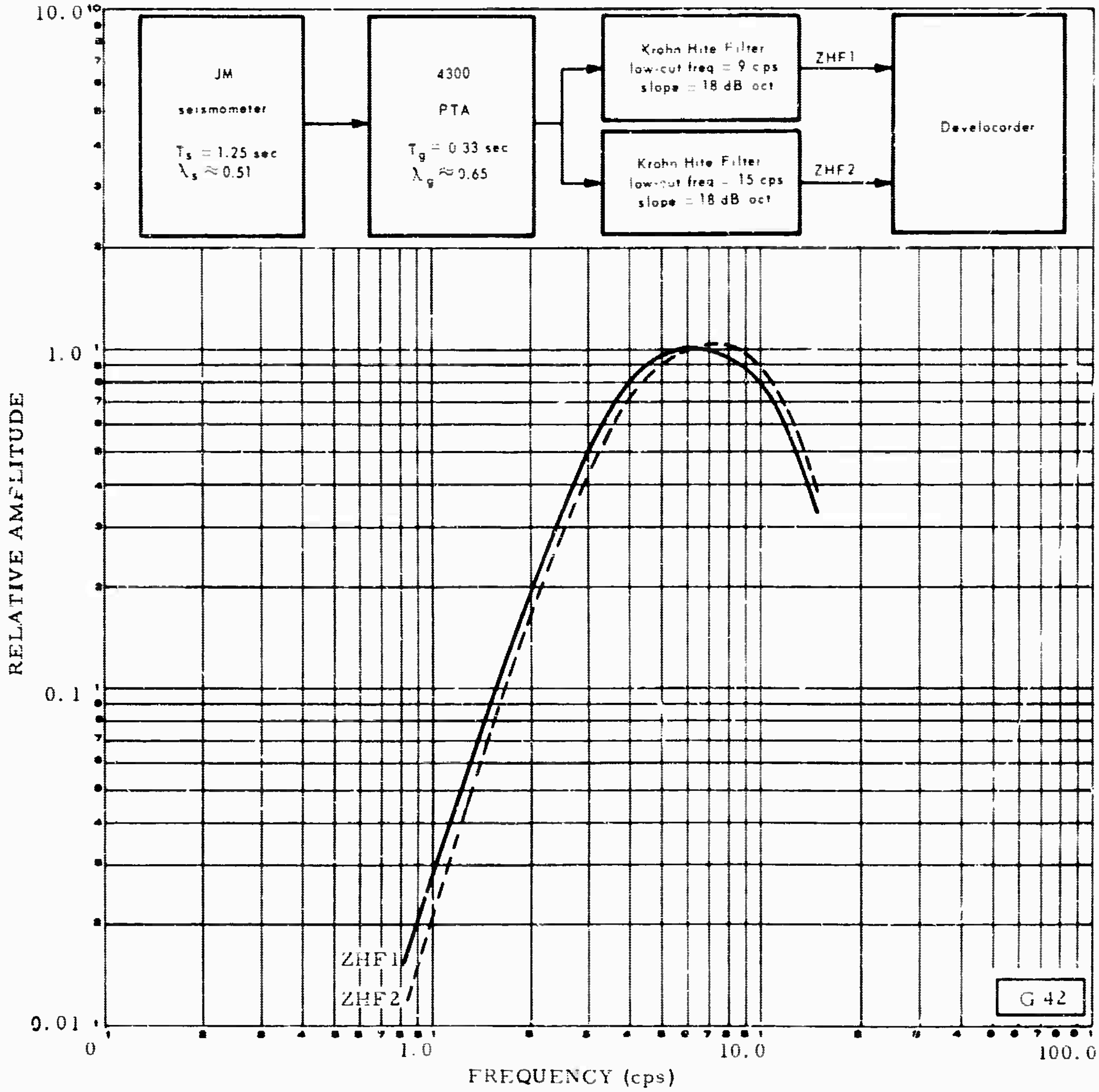


Figure 13. Frequency responses and block diagrams for ZHF1 and ZHF2.

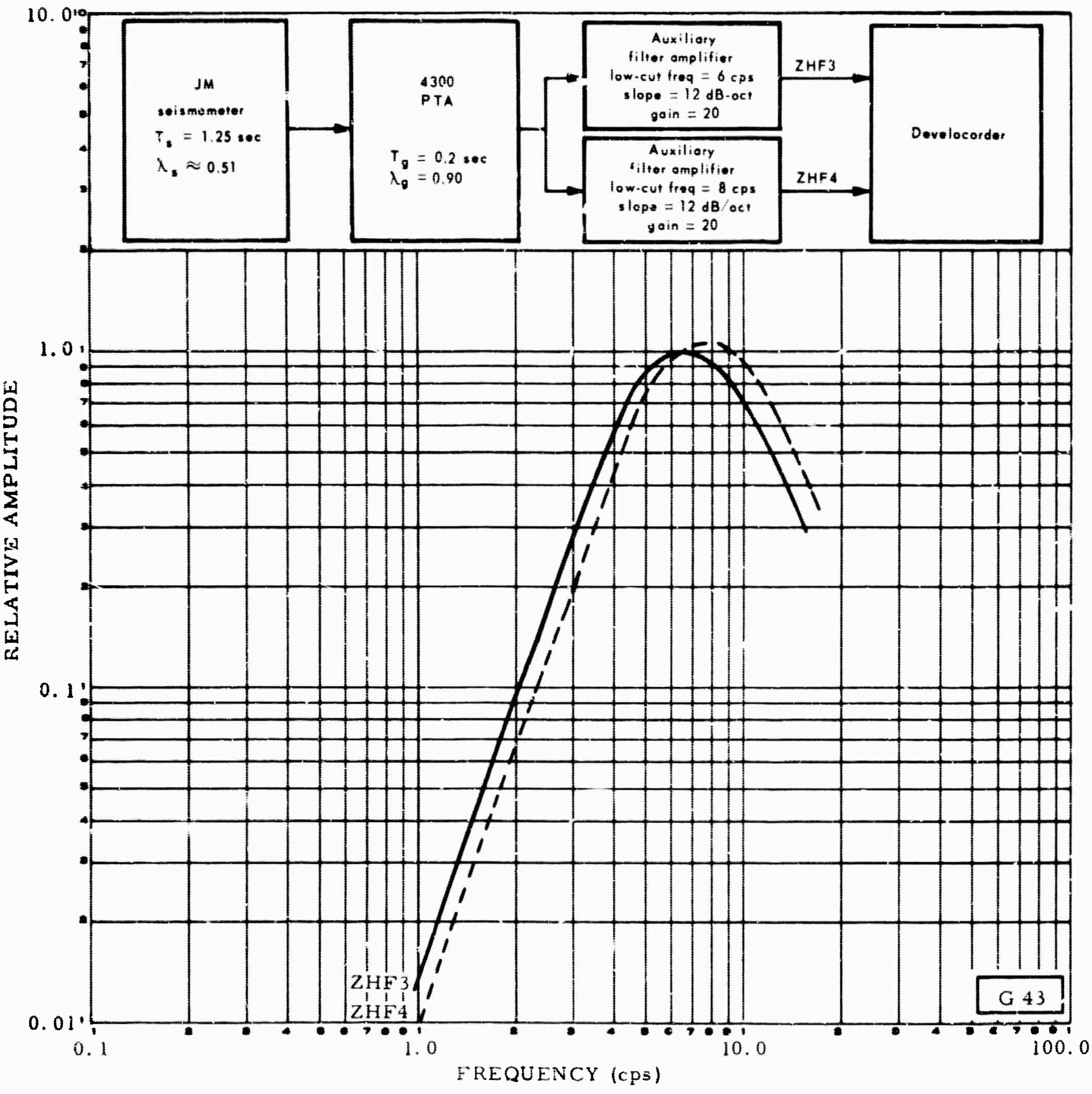


Figure 14. Frequency responses and block diagrams for ZHF3 and ZHF4.

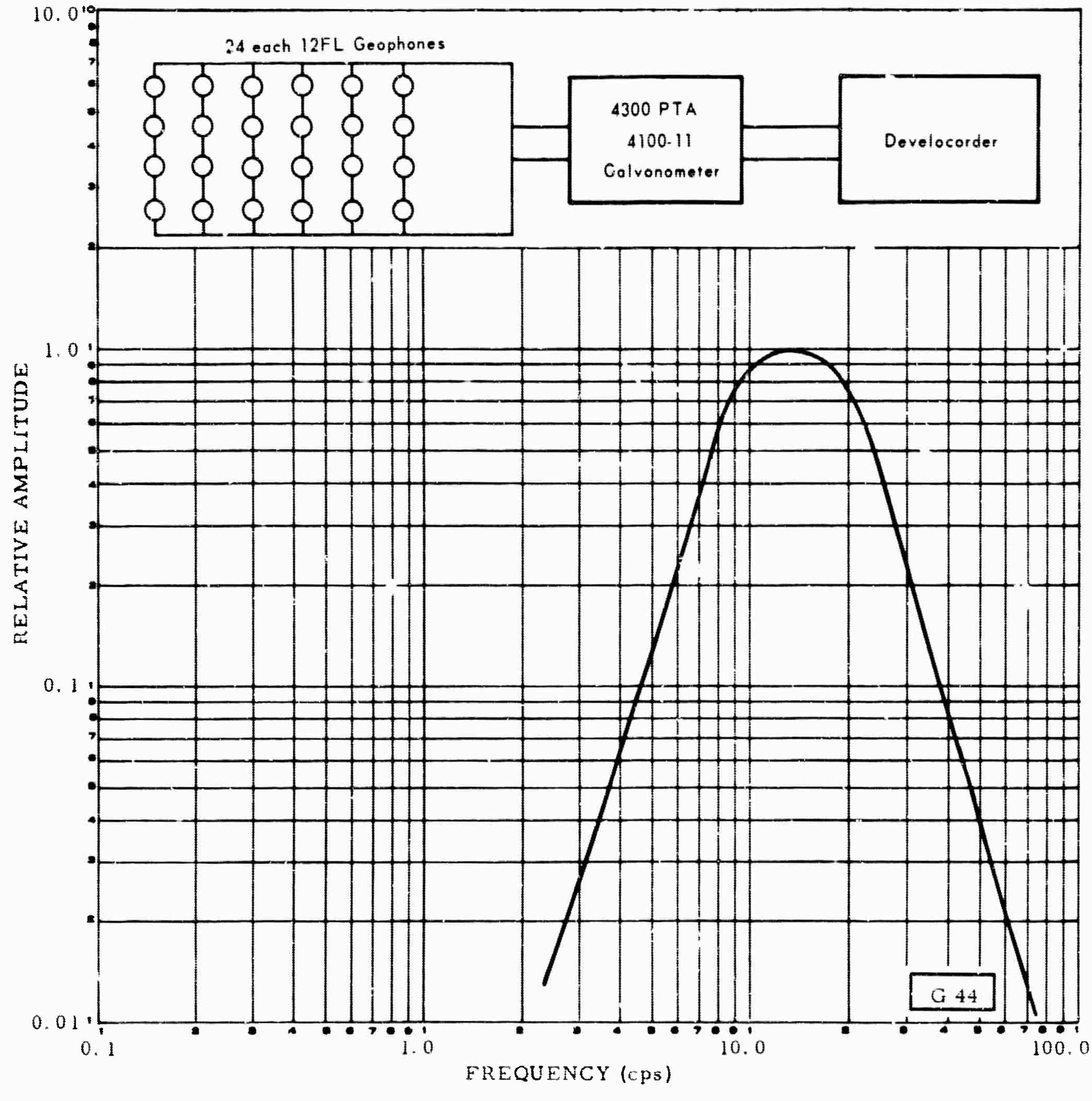
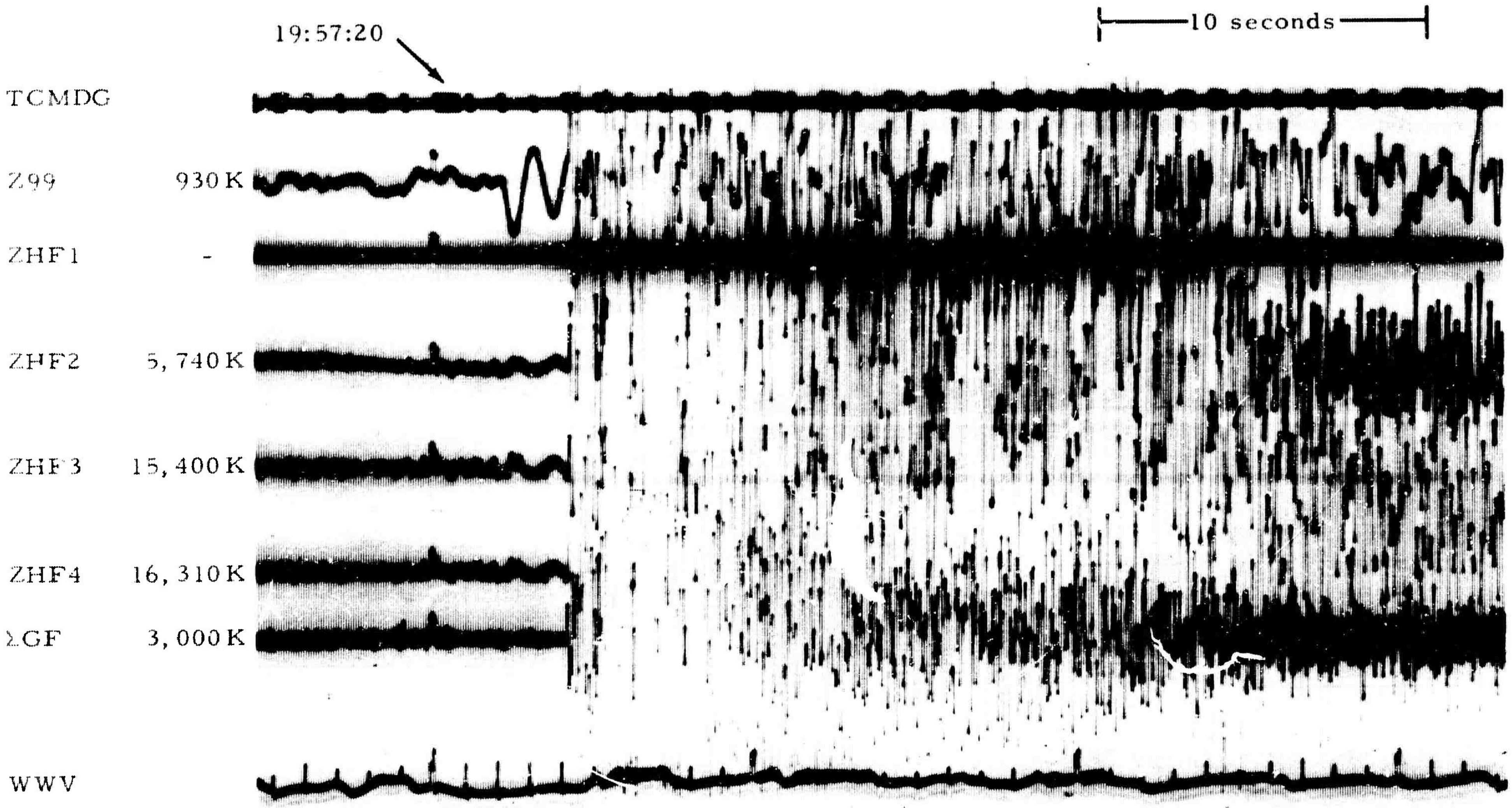


Figure 15. Block diagram and estimated frequency response for the Geophone seismograph (ΣGF).



TFSO
16 Sept 65
Run 259
DG 7162
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Figure 16 P arrival from Chase No. IV as recorded by the standard (Z99) and high-frequency short-period seismographs at TFSO. Note signal partially masked by local blast. (X10 enlargement of 16-mm film)

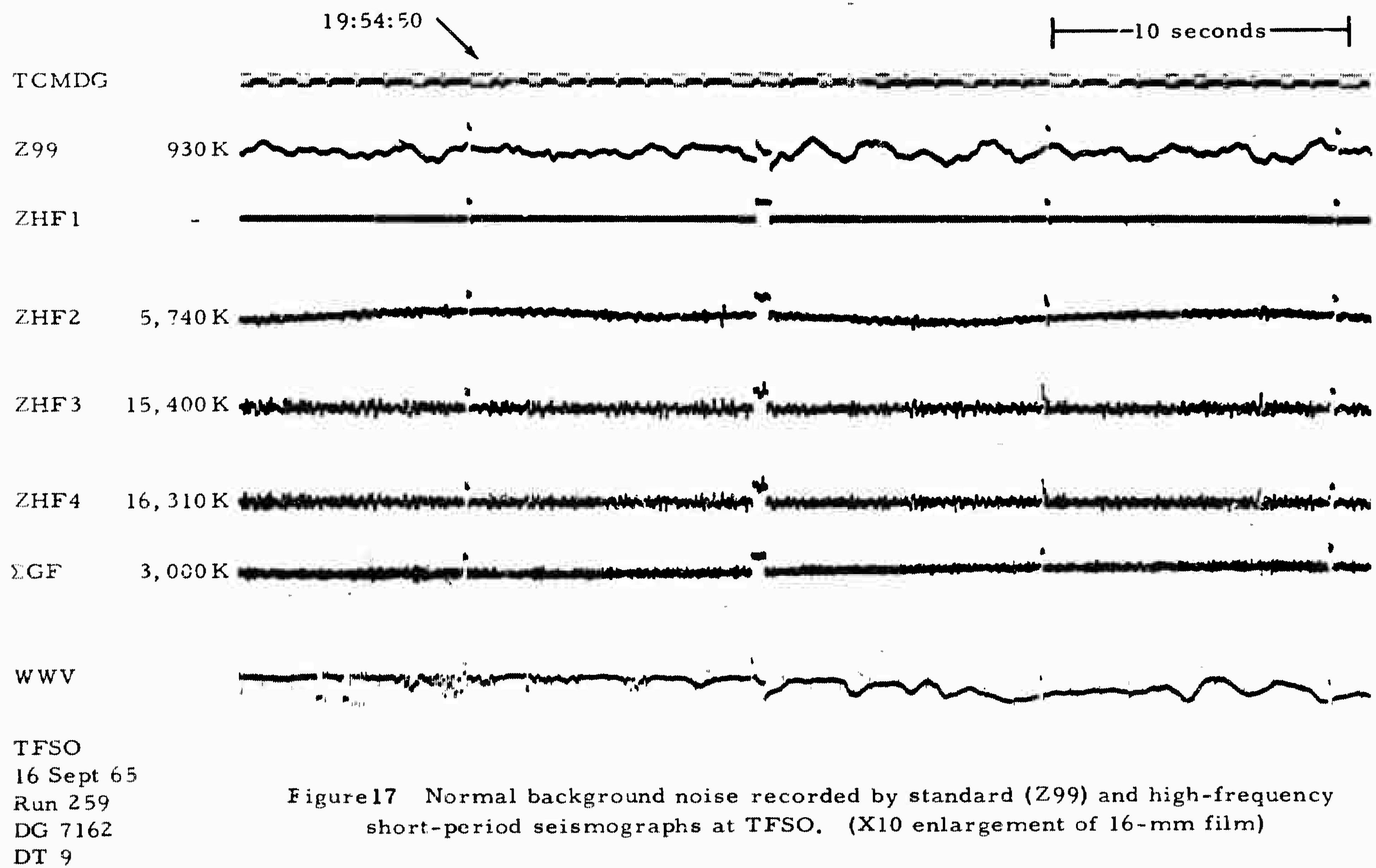

Figure 17 Normal background noise recorded by standard (Z99) and high-frequency short-period seismographs at TFSO. (X10 enlargement of 16-mm film)

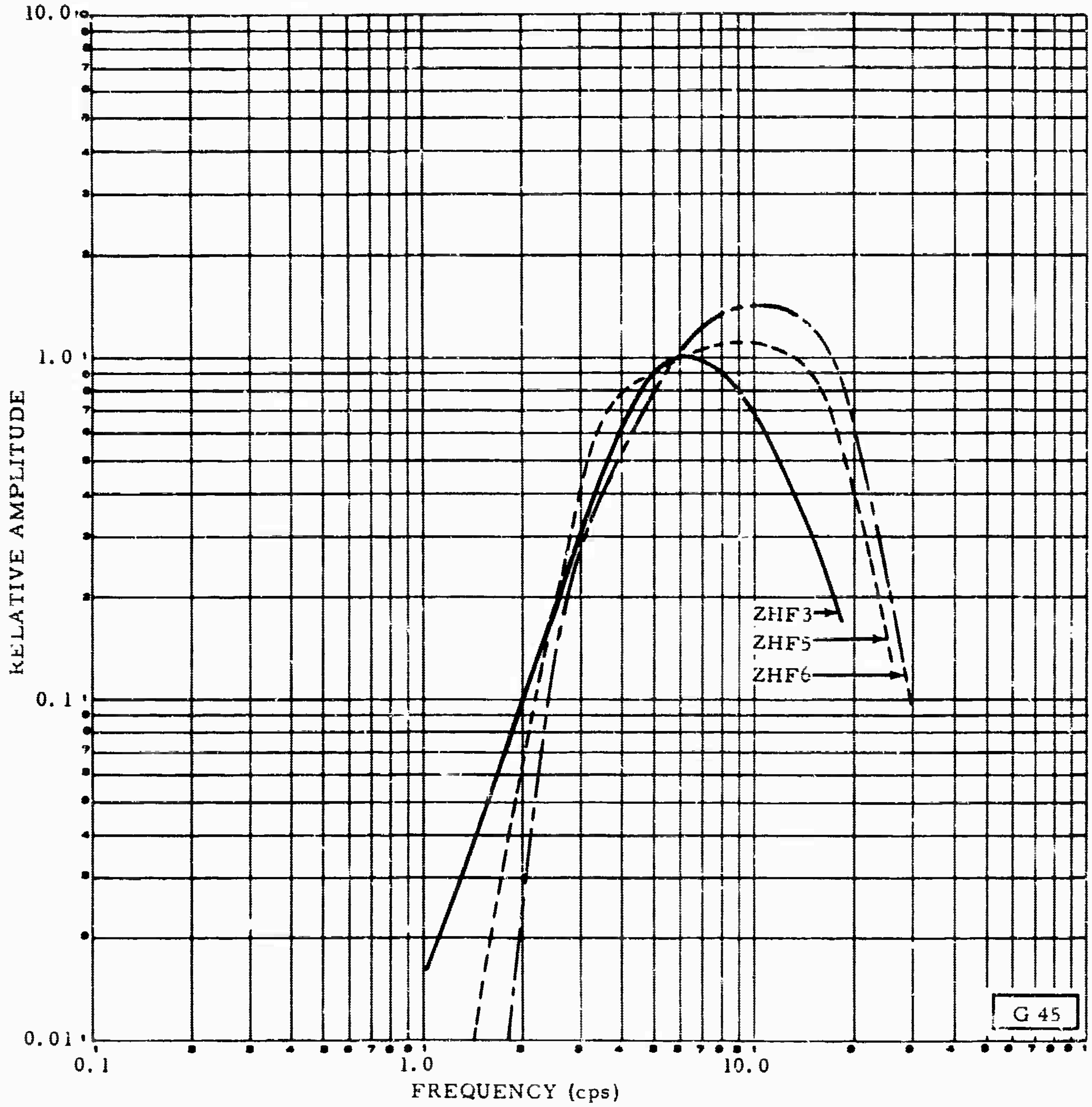

Figure 18. Frequency responses for the high-frequency seismographs. (These responses are plotted for constant amplitude input and apply to the film recordings.

Table 4. High-frequency seismograph recording intervals.

Period of operation	Develocorder	Tape (FM)	Tape (digital)
15 September to 13 October	ZHF 1 ZHF 2 ZHF 3 ZHF 4 ΣGF	ZHF 1 ZHF 2 ZHF 3 ZHF 4 ΣGF	
13 October to 20 October	ZHF 1 ZHF 2 ZHF 3 ZHF 4	ZHF 1 (hi, med, lo) ZHF 2 (hi, med, lo) ZHF 3 (hi, med, lo) ZHF 4 (hi, med, lo)	ZHF 1 (hi, med, lo) ZHF 2 (hi, med, lo) ZHF 3 (hi, med, lo) ZHF 4 (hi, med, lo)
20 October to Present	ZHF 3 ZHF 5 ZHF 6 ΣGF	ZHF 3 (hi, med, lo) ZHF 5 (hi, med, lo) ZHF 6 (hi, med, lo) ΣGF (hi, med, lo)	ZHF 3 (hi, med. lo) ZHF 5 (hi, med, lo) ZHF 6 (hi, med, lo) ΣGF (hi, med, lo)

KEY

ZHF 1	Peaked at 6cps	ZHF 4	Peaked at 8 cps
ZHF 2	Peaked at 8 cps	ZHF 5	Peaked at 10 cps
ZHF 3	Peaked at 6 cps	ZHF 6	Peaked at 10 cps

ΣGF Summation of Century Geophones

4.7 EFFECTS OF QUARRY AND MINE BLASTS ON TFSO ANALYSIS

A preliminary study to determine how TFSO's detection capability is affected by mine and quarry blasts was completed on 20 October. There are 26 known mine and quarry companies operating within a 400 km radius of TFSO which are sources of seismic signals recorded at TFSO. Figure 19 is a polar plot of the mine and quarry locations.

Data were taken from a typical week (Monday through Sunday) of recordings. If, in the analyst's opinion, the signal recorded from the blast had sufficient amplitude to mask a low-level teleseismic event, the signal was considered a significant occurrence, and the duration of signal was measured to the nearest five seconds. Figure 20 shows the total number of occurrences per day of signals generated by blasts, and figure 21 shows the total duration in minutes per day that blast signals could have masked low-level teleseismic events.

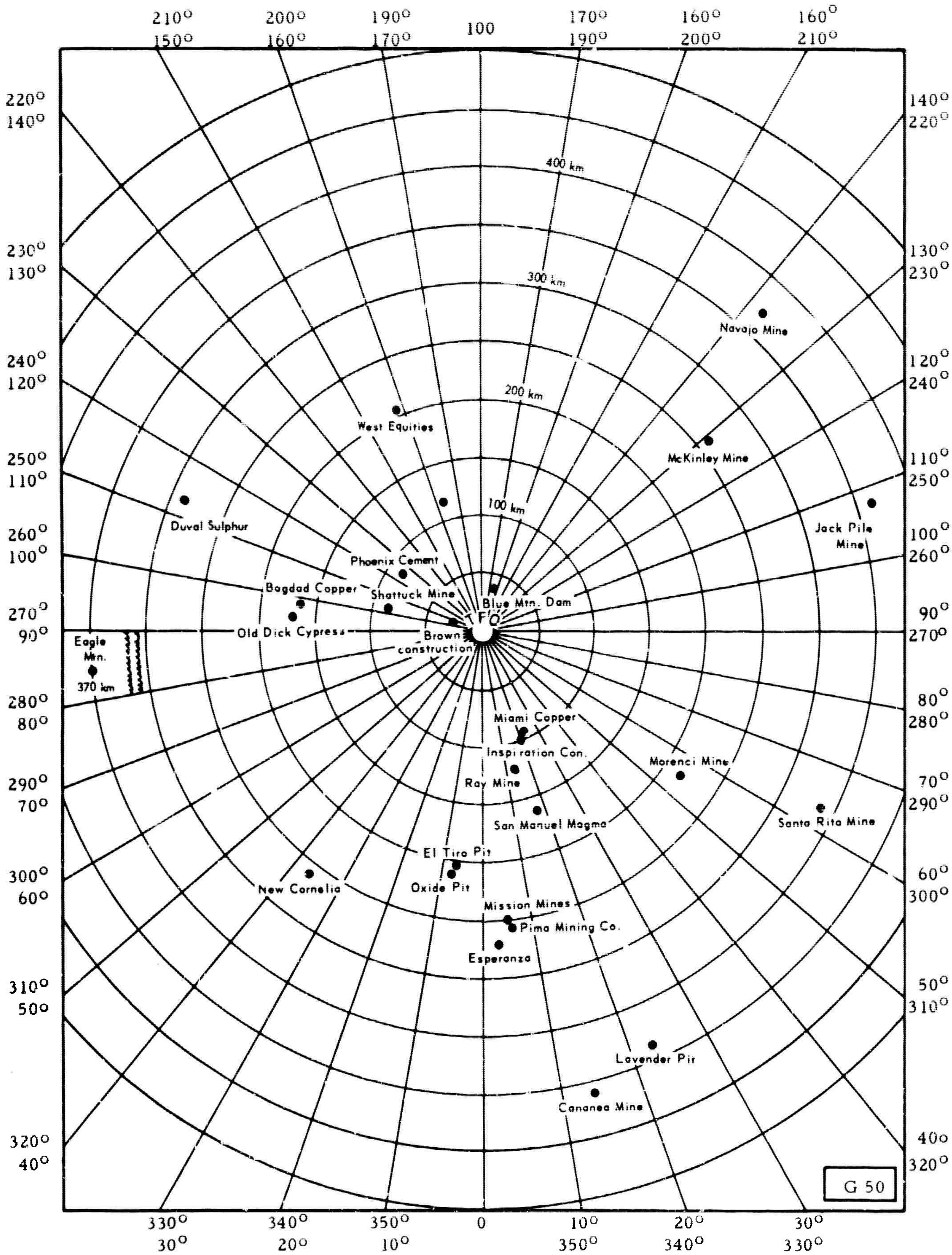

Figure 19. Location of quarry and mines within 400 km radius of TFSO.

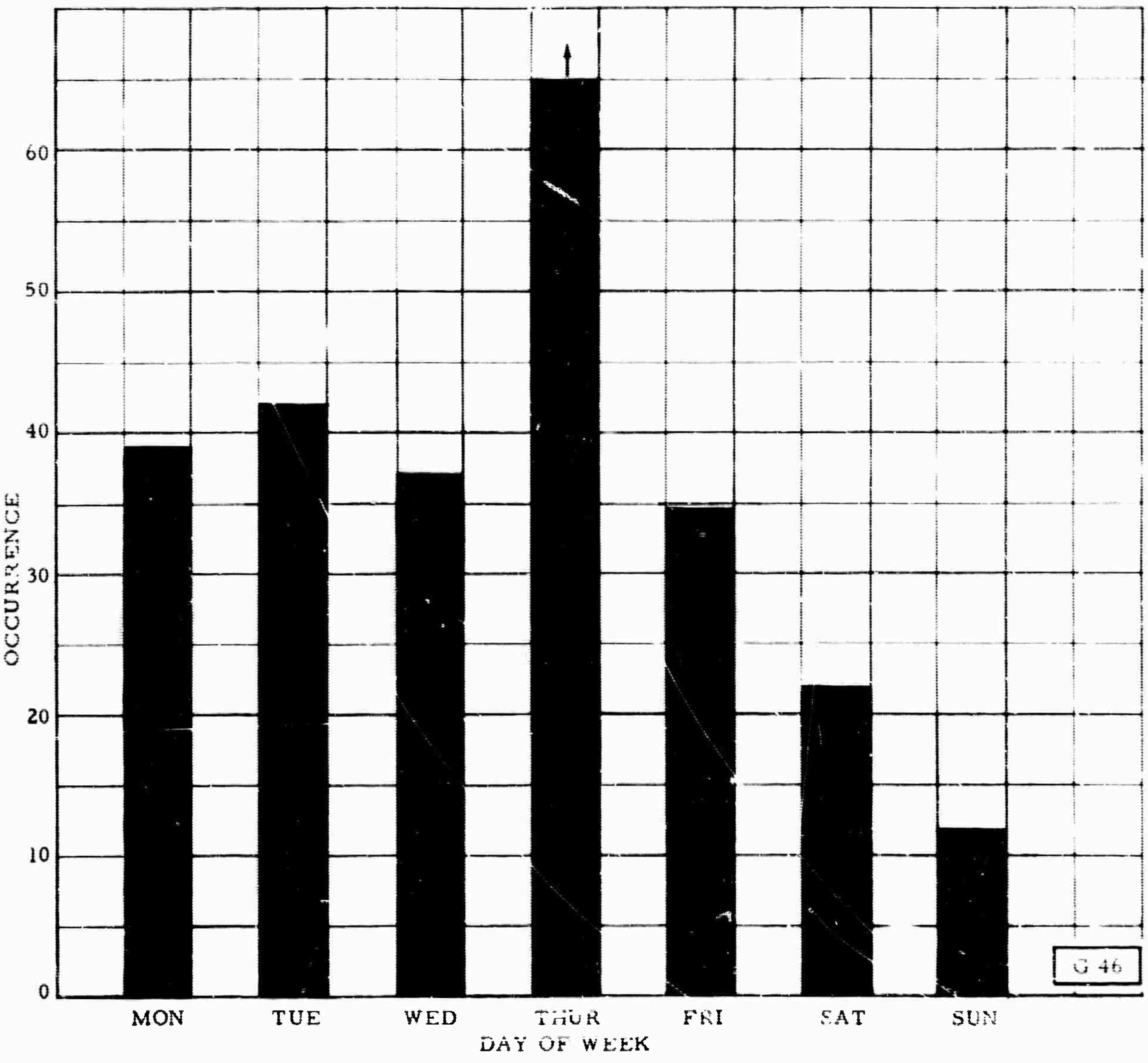

Figure 20. Number of quarry and/or mine blasts that occur per day.

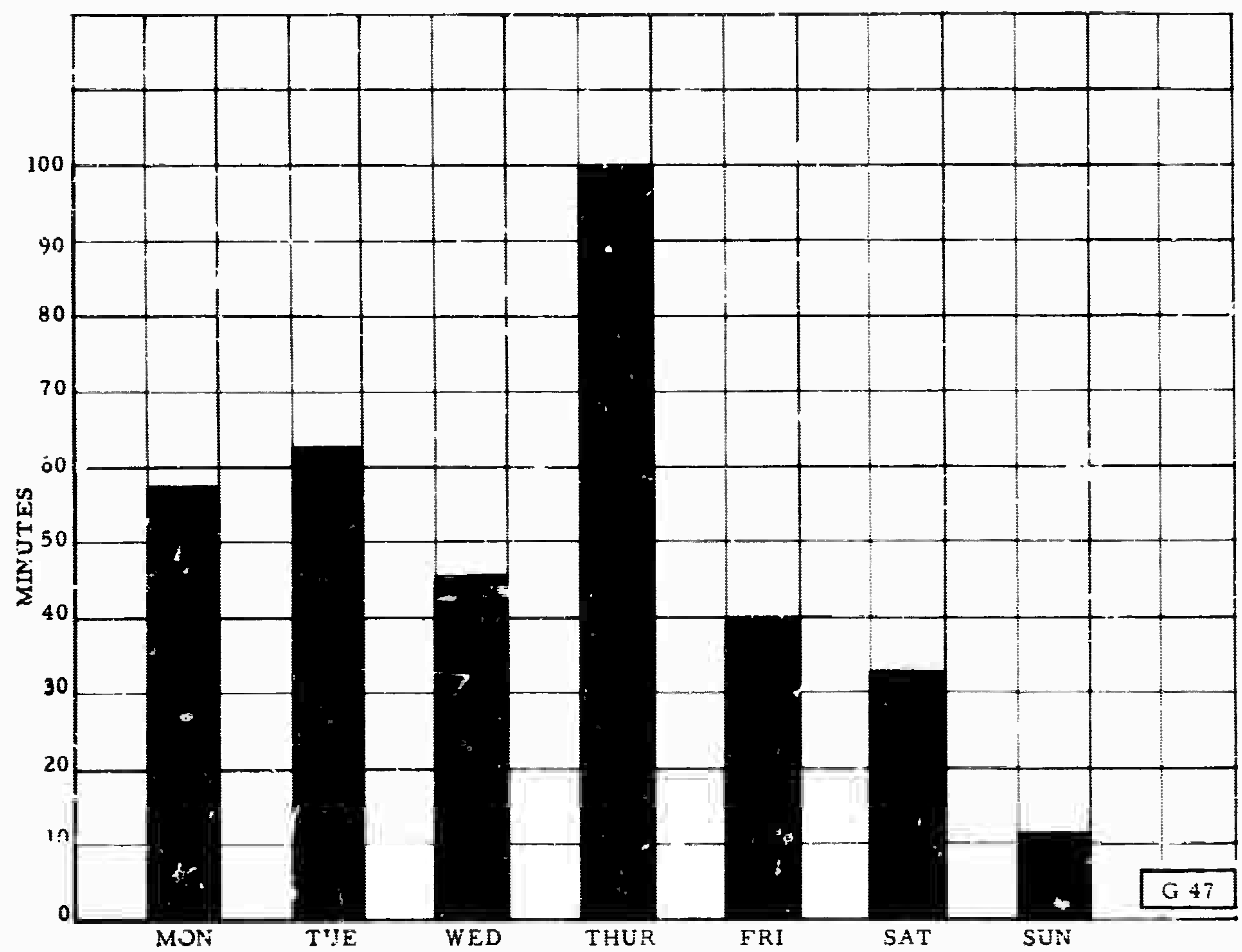

Figure 21. Total minutes of trace disturbance (capable of masking low-level signals) generated per day by quarry and/or mine blasts.

As seen in figures 20 and 21, blasts occur more frequently and the greater amount of trace disturbance occurs, on Thursday; the least amount occurs on Saturday and Sunday.

Figures 22 and 23 show that most of the trace disturbances occur between 1400Z through 2400Z and 2400Z through 0100Z which is to be expected since these are the normal working hours, 7:00 a.m. to 6:00 p.m.

Very few blasts occur between 0200Z and 1400Z. All events occurring within this time interval are thought to be natural events.

Figure 22 is a graph showing the total number of events recorded during the week plotted as a cumulative total for each hour of a 24-hour period. Figure 23 shows the total duration of time during the week that the events were observed on the records, also plotted as a cumulative total for each hour of a 24-hour period.

5. REPORTS AND DOCUMENTS

Fifty copies of TR 65-96, Operation of the Tonto Forest Seismological Observatory, Quarterly Report No. 1, Project VT/5055, 1 May through 31 July 1965, were mailed to the Project Officer 17 August 1965.

Copies of The Registration of Earthquakes at Blue Mountains Seismological Observatory, Cumberland Plateau Seismological Observatory, Tonto Forest Seismological Observatory, and Wichita Mountains Seismological Observatory during February 1965, published in three parts, was distributed on 24 August 1965.

Tests to confirm the proper operation of the Astrodata System at TFSO were sent to the Project Officer on 31 August 1965.

On 9 September, the Project Officer was sent a copy of the Monthly Fiscal Report to Comptroller United States Air Force for Contracts 12373, 13562, and 14444.

A report on the TFSO high-frequency system was sent to the Project Officer on 22 September 1965. Blue-line prints of the high-frequency system were mailed on 28 September 1965.

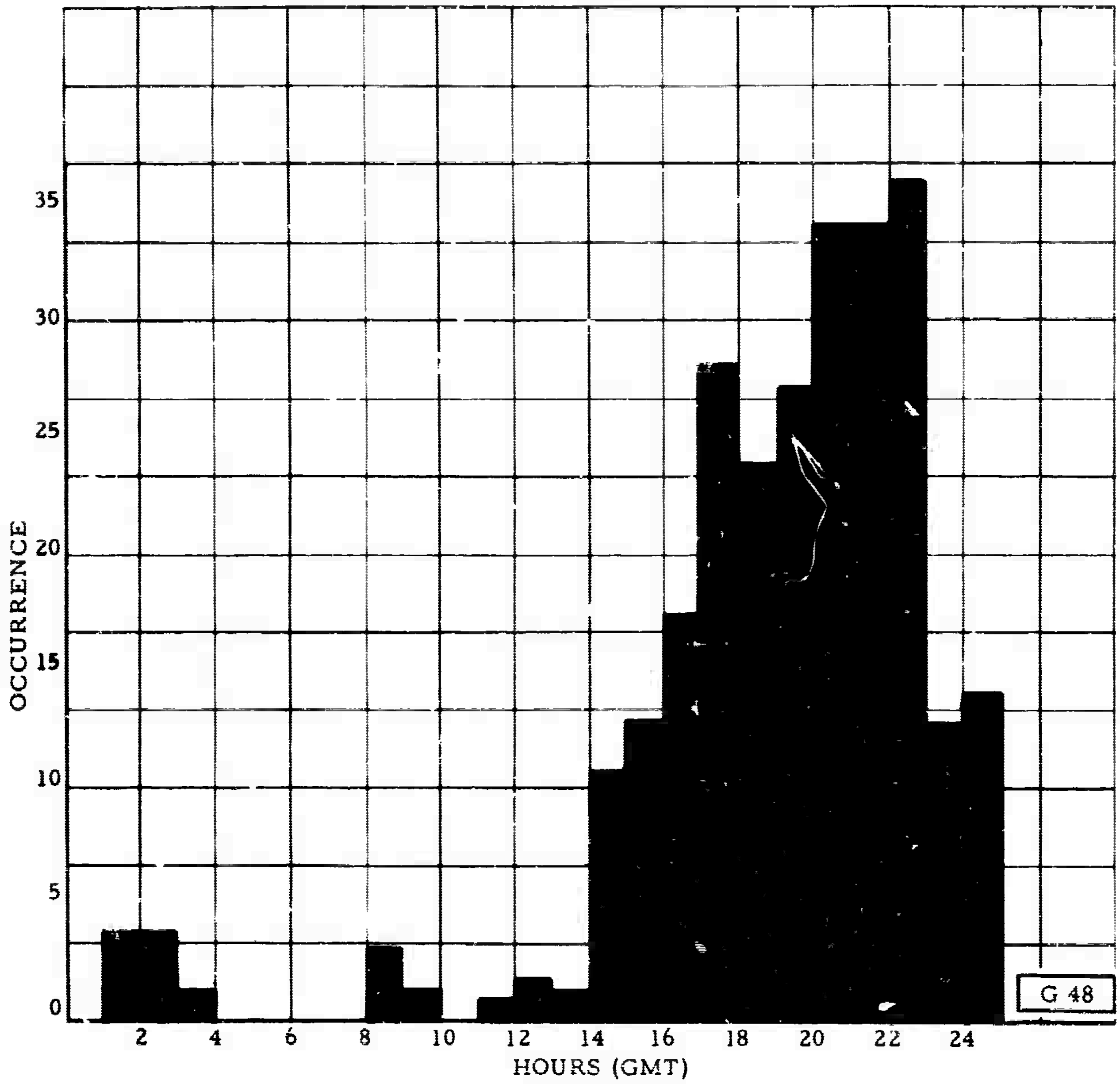

Figure 22. Occurrence of quarry and/or mine blasts per week at a given time.

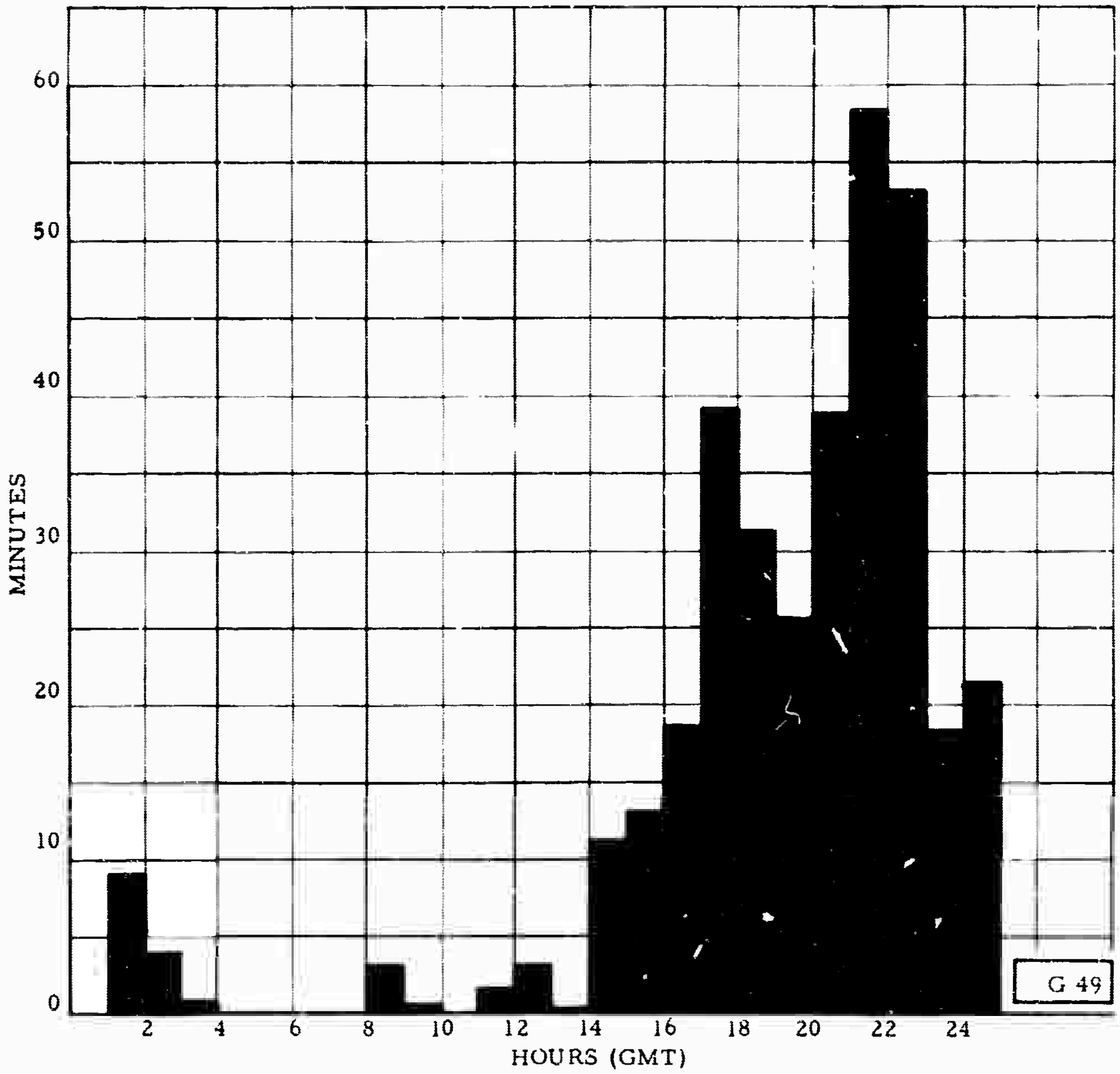

Figure 23. Total minutes of trace disturbance (capable of masking low-level signals) generated from mine or quarry blasts per week at a given hour.

Copies of The Registration of Earthquakes at Blue Mountains Seismological Observatory, Cumberland Plateau Seismological Observatory, Tonto Forest Seismological Observatory, and Wichita Mountains Seismological Observatory during April 1965, published in two parts, was distributed on 30 September 1965.

On 30 September, the Project Officer was mailed a copy of the August 1965 Monthly Fiscal Report to Comptroller United States Air Force for Contracts 12373. 13562, and 14444.

Transmittal of March 1965 Five-Station Bulletin Data to SDL was accomplished on 4 October 1965. The July 1965 Raw Earthquake Bulletin Data was sent on 6 October 1965.

Prints of TFSC's high-frequency recordings were sent to the Project Officer on 5 October 1965.

Copies of The Registration of Earthquakes at Blue Mountains Seismological Observatory, Cumberland Plateau Seismological Observatory, Tonto Forest Seismological Observatory, and Wichita Mountains Seismological Observatory during April 1965, published in two parts, was distributed on 12 October 1965.

Reports on two topics, Vapor Barrier Installation at TFSO and High-Frequency Seismographs-Noise Tests were submitted to the Project Officer on 14 October 1965.

The August 1965 16-Millimeter Film Seismograms, the September 1965 Magnetic-Tape Seismograms, and Logs and, the January 1965 Five-Station Bulletin Data were sent to SDL on 19 October 1965. Frequency-response data were sent on 22 October 1965.

A copy of the September 1965 Monthly Fiscal Report to Comptroller United States Air Force for Contracts 12373, 13562, and 14444 was sent to the Project Officer on 25 October 1965.

Transmittal of May 1965 Five-Station Bulletin Data to SDL was accomplished on 25 October 1965.

A list of Milestones was published and a copy was sent to the Project Officer on 29 October 1965.

APPENDIX to TECHNICAL REPORT NO. 6_-129

STATEMENT OF WORK TO BE DONE

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STATEMENT OF WORK TO BE DONE
AFTAC PROJECT AUTHORIZATION NO. VELA T/5055

1. Operation.

a. Operate the Tonto Forest Seismological Observatory (TFSO), normally recording data continuously.

b. Evaluate the seismic data to determine optimum operational characteristics ard make changes in the operating parameters as may be required to provide the most effective observatory possible. Addition of new and modification of present on-line instrumentation are within the scope of work. However, such instrument additions and modifications, data evaluation, and major parameter changes are subject to prior technical approval by the AFTAC project officer.

c. Conduct routine daily analysis of seismic data and transmit daily seismic reports to the US Coast and Geodetic Survey, Washington, DC 20230, using the established report format and detailed instructions.

d. Record the results of daily analysis in a format compatible with the automated bulletin program (ABP) used by the Seismic Data Laboratory (SDL), 300 North Washington Street, Alexandria, Virginia 22314, in their preparation of the seismological bulletin of the VELA-UNIFORM seismological observatories. This format may be established by coordination with SDL through the AFTAC project officer. The schedule of routine shipments of this data to SDL will be established by the AFTAC project officer.

e. Conduct quality control (QC), as necessary, to assure the recording of high quality data on both magnetic tape and film. Past experience indicates that QC review of one magnetic tape per magnetic tape recorder per week is satisfactory unless QC tolerances have been exceeded and the necessity of additional QC arises. QC of magnetic tape should include, but need not necessarily be limited to, the following items:

(1) Completeness and accuracy of operation logs.

(2) Accuracy of observatory measurements of system noise and equivalent ground motion.

(3) Quality and completeness of voice comments.

(4) Examination of all calibrations to assure that no clipping occurs.

(5) Determination of relative phase shift among all array seismograph systems.

(6) Measurement of DC unbalance.

Atch 1

(7) Presence and accuracy of tape calibration and alignment.

(8) Check of uncompensated noise on each channel.

(9) Check of uncompensated signal-to-noise of channel 7.

(10) Check of general strength and quality of WWV time.

(11) Check of synchronization of digital time code with WWV.

f. Continue telephone service and VHF telemetry between TFSO and the mobile seismic vans (Project VELA T/4051) located along extensions of the TFSO crossed array.

g. Provide observatory facilities, accompanying technical assistance by observatory personnel, and seismological data to requesting organizations and individuals after AFTAC approval through the project officer.

h. Maintain, repair, protect, and preserve the facilities of TFSO in good physical condition in accordance with sound industrial practice.

2. Instrument Evaluation.

a. On approval by the AFTAC project officer, evaluate the performance characteristics of experimental and off-the-shelf equipment offering potential improvement in the performance of observatory seismograph systems. Operation and test of the instrumentation under field conditions should normally be preceded by laboratory test and evaluation.

b. To permit more thorough laboratory evaluations to be conducted at TFSO, improvements to TFSO laboratory capability may be necessary. The contractor should make recommendations for such improvements and, after approval by the AFTAC project officer, implement them.

3. Developmental Function. Operation and evaluation of the observatory's "standard" instrumentation and of "experimental" equipment may disclose the need for supplemental equipment, neither commercially available nor in development under the VELA-UNIFORM program, that could improve the performance and capability of the seismograph systems of TFSO and other VELA-UNIFORM observatories. The contractor should make recommendations on the development of such equipment and, after approval by the AFTAC project officer, proceed with developmental work.

4. Research Programs. On approval by or at the request of the AFTAC project officer, conduct research programs designed to upgrade the TFSO detection capability. Environmental conditions (geological, seismological, and meteorological) affecting the results of these research programs should not be neglected. Research might pursue investigations in, but are not necessarily limited to, the following areas of interest:

a. Microseismic Noise.

(1) Review all available TFSO noise data to guide the direction of additional work. Define and conduct additional surface noise studies as necessary.

(2) Examine noise at shallow depths using existing and additional shallow boreholes. The number, depth, and locations of the additional boreholes must be approved by the AFTAC project officer.

b. Array Detection Capability.

(1) Evaluate combinations of existing vertical and of existing horizontal surface array seismographs to determine the most effective array summations in detecting teleseismic signals. Determine TFSO overall detection capability when using these array summations along with the remaining seismograph systems.

(2) Under Project VELA T/5052, AFTAC has programmed the addition of a multiple array processor to the TFSO instrumentation for the summer of 1965; training in operation, maintenance, and calibration of the processor and in analysis techniques will be provided to appropriate TFSO personnel at the time of installation by the manufacturer, Texas Instruments Incorporated. Evaluate the detection capability of the processor and examine its enhancement, if any, of the overall TFSO capability.

(3) Mobile seismic vans (Project VELA T/4051) are temporarily located along extensions of the TFSO crossed array and the data (3-component short-period) from the vans are recorded at TFSO. Investigate the use of this extended array to improve the TFSO detection capability.

(4) Determine TFSO deficiencies, if any, that degrade the observatory's detection capability. Prepare and submit to the AFTAC project officer recommended improvements designed to eliminate such deficiencies and enhance the detection capability.

c. Visual Data Presentation. Investigate forms of visual data presentation which would improve detection of seismic signals by visual on-line analysis.

Programs implemented should be planned for completion during the contracted period of TFSO operation. Furthermore, prior to commencing any research program, AFTAC approval must be obtained of a comprehensive outline for each research program instituted.